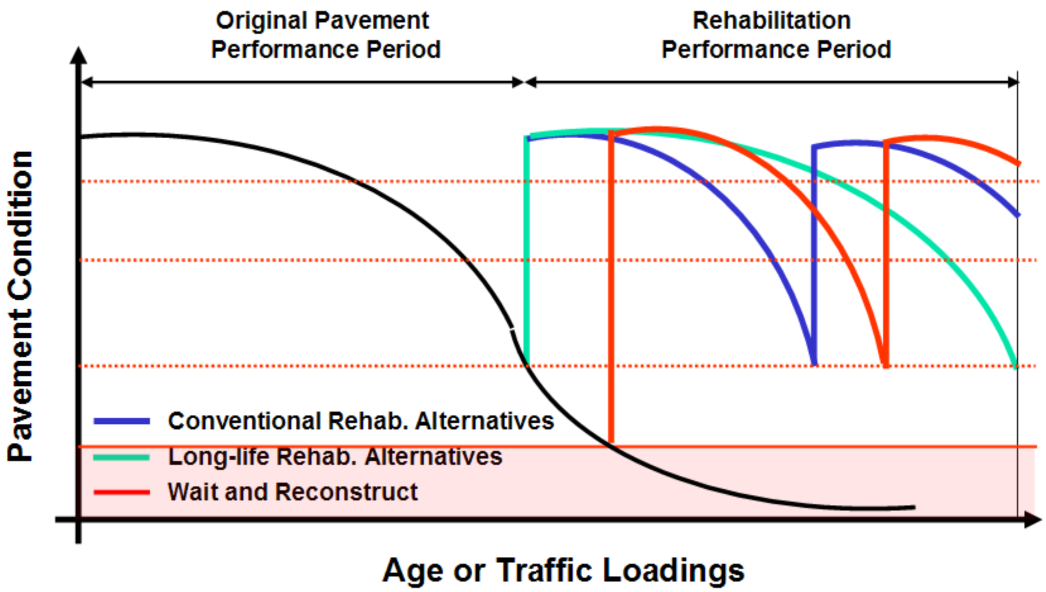
LIFE-CYCLE COST ANALYSIS PROCEDURES MANUAL



Note to the User

To use this manual, the reader must have the life-cycle cost analysis software program *RealCost*, *Version 2.2 California Edition*. The program can be downloaded from:

http://www.dot.ca.gov/hq/esc/Translab/OPD/DivisionofDesign-LCCA.htm

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State of California
Department of Transportation
Pavement Standards Team & Division of Design

DISCLAIMER

This manual is intended for the use of Caltrans and non-Caltrans personnel on projects on the State Highway System regardless of funding source. Engineers and agencies developing projects off the State Highway System may use this manual at their own discretion. Caltrans is not responsible for any work outside of Caltrans performed by non-Caltrans personnel using this manual.

ACKNOWLEDGMENT

The information contained in this manual is a result of efforts of many individuals in the Department of Transportation, Pavement Standards Team, Division of Design, and the University of California, Partnered Pavement Research Center. Questions regarding this manual should be directed to Mario Velado at (916) 227-5843 or Mario_Velado@dot.ca.gov.

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CHAPTER 1 - INTRODUCTION

1.1 Purpose of This Manual

This manual describes Life-Cycle Cost Analysis (LCCA) procedures to be used on pavement projects on the State Highway System, regardless of funding source. The manual provides step-by-step instructions for using *RealCost, a* macro inside EXCEL, developed by the Federal Highway Administration (FHWA). *RealCost* was chosen by Caltrans as the official software for evaluating the cost effectiveness of alternative pavement designs for new roadways or for existing roadways requiring CApital Preventive Maintenance (CAPM), rehabilitation, or reconstruction. *RealCost* and the manual can be accessed from the Caltrans Website at http://www.dot.ca.gov/hq/esc/Translab/OPD/DivisionofDesign-LCCA.htm. This manual provides the guidelines required to perform an LCCA and will help to assure that project alternatives are analyzed objectively and consistently statewide, regardless of who designs, builds, or funds the project.

1.2 Background

LCCA is an analytical technique that uses economic principles in order to evaluate long-term alternative investment options. The analysis enables total cost comparison of competing design alternatives with equivalent benefits. LCCA accounts for relevant costs to the sponsoring agency, owner, operator of the facility, and the roadway user that will occur throughout the life of an alternative. Relevant costs include initial construction (including project support), future maintenance and rehabilitation, and user costs (time and vehicle costs). The LCCA analytical process helps to identify the lowest cost alternative that accomplishes the project objectives by providing critical information for the overall decision-making process. However, in some instances, the lowest life-cycle cost option may not ultimately be selected after such considerations as available budget, constructibility and maintainability issues, and environmental concerns are taken into account.

1.3 Caltrans' Policy

FHWA encourages the use of LCCA for the evaluation of all major investment decisions in order to increase the effectiveness of those decisions. It is Caltrans' policy that the cost impacts of a project's life-cycle are fully taken into account when making project-level decisions for pavements[1].

Life-cycle cost analysis must be performed, using the procedures and data in this manual. LCCA must be performed for all projects that include pavement work on the State Highway System except:

- Major maintenance (HM-1)
- Minor A and Minor B
- Permit Engineering Evaluation Reports (PEER)
- Maintenance pullouts
- Landscape paving

For the exempted projects, the project manager and the project development team will determine on a case-by-case basis if a life-cycle cost analysis should be done and how it should be documented for each project development phase. For all other projects that include pavement work, **exemptions from LCCA shall be submitted to the Chief Office of Pavement Engineering for approval, and documented in the project documents.**

[1] See Memorandum "Use of Life Cycle Cost Analysis for Pavements" by Richard Land, Chief Engineer dated March 7, 2007.

To document life-cycle costs in project documents follow the procedures in Appendix O-O of the Project Development Procedures Manual (PDPM). When the alternative with the lowest life-cycle cost is not selected, the reasons must also be documented.

Pavement work consists of all the work associated with constructing a pavement structure, including subgrade, subbase, base, surfacing, and pavement drainage. It can consist of constructing, widening, rehabilitating, or overlaying lanes, shoulders, gore areas, intersections, parking lots, or other similar activities.

This manual is intended to provide the procedures required to implement the LCCA policies. LCCA must conform to the procedures and data in this manual. **Life-cycle cost analysis performed as part of a Value Analysis study can only be used to meet the requirements for LCCA in HDM 619 and Project Development Procedures, Chapter 8 if the analysis is done in accordance with the requirements found in the Life-Cycle Cost Analysis Procedures Manual for pavements.**

The manual will be updated with new data and information periodically or as required. Additional information can be found in Chapter 8 of the PDPM and in Topics 612 and 619 of the Highway Design Manual (HDM). This manual shall supersede any conflicting procedures and data found in the PDPM and HDM.

Highway Design Manual Topics 612 and 619 identify situations where a LCCA must be performed to assist in determining the most appropriate alternative for a project by comparing the life-cycle costs of different:

1) Pavement types (flexible, rigid, or composite);
2) Rehabilitation strategies;

3) Pavement design lives (e.g., 5 vs. 10 years, 10 vs. 20 years, 20 vs. 40 years, etc.); and
4) Implementation strategies (combining widening and rehabilitation projects vs. constructing them separately).

If a change in pavement design alters the pavement design life or other performance objectives during the design of the project, update the LCCA.

CHAPTER 2 – LCCA APPROACHES AND POLICY REQUIREMENTS

2.1 LCCA Approaches

There are two different approaches in life-cycle cost computation: deterministic and probabilistic. The deterministic approach is the traditional methodology in which the user assigns each LCCA input variable a fixed, discrete value usually based on historical data and user judgment. The probabilistic approach is a relatively new methodology that accounts for the uncertainty and variation associated with input values. The probabilistic approach allows for simultaneous computation of different assumptions for many variables by defining uncertain input variables with probability distributions of possible values. Probability distribution functions for individual LCCA input variables are still under development by Caltrans and are not yet available for use. **Therefore, Caltrans only uses the deterministic approach at this time.**

2.2 LCCA Policy Requirements

2.2.1 Timing

Once the decision has been made to undertake a project, a life-cycle cost analysis (LCCA) should be completed as early as possible in the project development process. Caltrans practice is to perform a LCCA when scoping a project (Project Initiation Document phase) and again during the Project Approval & Environmental Document phase (PA&ED).

With the exception of rehabilitation (code 120, 122, and 125) and CAPM (code 121) projects, the life-cycle cost analysis can be deferred from the scoping phase to the PA&ED phase at the discretion of the district if any of the following apply:

1. Construction costs will not be programmed from the Project Initiation Document, such as the Project Study Report-Project Development Support (PSR-PDS).

2. Project is programmed for construction using the pavement and traffic control costs for the alternative with the higher initial costs.

Any deferral of the life-cycle cost analysis should be documented in the Project Initiation Document and should include the necessary resources to complete the analysis during the PA&ED Phase of the project. Life-cycle cost analysis must be completed prior to the PA&ED date.

2.2.2 Elements

The elements required to perform a LCCA are:

1) Design alternatives;
2) Analysis period;
3) Discount rate;
4) Maintenance and rehabilitation sequences;
5) Costs;
6) *RealCost* software

2.2.3 Source

The LCCA procedures described herein were derived from the FHWA's *RealCost User Manual* (2004) and *LCCA Technical Bulletin* (1998), "Life-Cycle Cost Analysis in Pavement Design," and the *Life-Cycle Cost Analysis Primer* (2002). The additional tables, figures, and other resources included in this manual are specifically developed for Caltrans projects to guide the data inputs needed for running *RealCost*.

2.3 Design alternatives

A LCCA begins with the selection of alternative pavement designs that will accomplish the same performance objectives for a project. For example, comparisons can be made between flexible vs. rigid pavements; rubberized hot mix asphalt (RHMA) vs. conventional hot mix asphalt (HMA) pavements; HMA mill-and-overlay vs. HMA overlay; and 20-year vs. 40-year pavement design lives. Each competing alternative, if properly designed, must be a viable pavement structure that is both constructible and cost effective for that type and life of pavement.

2.3.1 Provisions for Selecting Design Alternatives

When selecting design alternatives for the LCCA, the following provisions must be met:

1) Compare pavement alternatives with different design lives:

   At least two of the competing alternatives must have the same type of surface material, but with different pavement design lives. [i.e. Flexible: HMA, RHMA, Rigid: Jointed Plain Concrete Pavement (JPCP), Continuously Reinforced Concrete Pavement (CRCP), etc]

2) Compare pavement alternatives with different surface material:

   When comparing a flexible and a rigid pavement alternative with different pavement design lives, another flexible alternative matching the design life of the rigid alternative must also be analyzed. Exceptions to this provision include situations where no standard design with an alternate design life exists for the pavement surface in question. [Examples: no standard flexible pavement design for a Traffic Index (TI) > 15; no continuously reinforced concrete pavement (CRCP) designs for High Mountain or High Desert climate regions].

3) Rubberized Hot Mix Asphalt (RHMA) must be one of the competing alternatives when flexible pavement is being considered unless RHMA is not viable for the project. If RHMA is not a viable alternative, justification must be included in the Project Initiation Document (PID) or the Project Report (PR). For further information on when and how to use RHMA, see HDM Index 631.3 and the Asphalt Rubber Usage Guide.

4) During the PID phase, LCCA must at least determine which alternate pavement design life is the most cost effective. Refer to the beginning of this Chapter 2 for the possible deferral of the LCCA to the PA&ED phase.

HDM Topic 612 provides the minimum requirements used to determine the pavement design lives for each type of project. Caltrans currently investigates the following alternate pavement design lives:

- 20-year
- 40-year
- CAPM projects: no specific design life, 5 to 10-year anticipated service life
- Widening projects: match remaining service life of adjacent roadway

Note:

Remaining service life (RSL) is determined by the District Maintenance or Materials Engineer by estimating, in 5-year increments, how much life (before a CAPM project will be needed) remains in the existing pavement adjoining the widening project. Per HDM Index 612.3, the pavement design life of the widening cannot be less than the design period (HDM 103.2) of the project. For example, if the existing pavement on a widening project has an estimated RSL of 15 years and the design period for the widening project is 20 years, then the pavement design life for the widening project is 20 years.

5) For rehabilitation and CAPM projects, determine the type of pavement (flexible vs. rigid/composite, HMA vs. RHMA, JPCP vs. CRCP) during the PID phase.

6) For new construction or widening projects, determination of the pavement surface type can be deferred until the PA&ED phase (if desired by the district) because information is often limited during the PID phase. Preliminary decisions made during the PID phase regarding pavement type must be verified during the PA&ED phase.

   If the pavement surface type cannot be determined during the PID phase and the construction budget will be programmed using the PID document, determine the pavement costs as follows:

   a) For widening:

      - Select the same pavement type as the existing (flexible, rigid, or composite), except when the TI > 15 use composite pavement in lieu of flexible pavement. (Caltrans currently does not have a flexible pavement design for TI > 15)

      - If flexible is the expected alternative, assume the surface type is RHMA

   b) For new construction:

      - TI $\leq$ 10: assume flexible pavement

      - 10 < TI $\leq$ 15: assume rigid or flexible pavement. Historically, Caltrans has used rigid pavement on freeways and expressways, and flexible pavement on conventional highways. If there is uncertainty which alternative is best for the project situation, the alternative with the higher initial cost should be selected for programming.

- 15 < TI ≤ 17: assume rigid or composite pavement
- TI > 17: assume CRCP as the preferred rigid pavement alternative

For new construction projects with a 20-year TI > 10, a LCCA analysis comparing rigid or composite and flexible pavement alternatives must be done at the PA&ED phase, even if an analysis was previously completed during the PID phase.

7) The alternatives being evaluated must provide equivalent improvements or benefits. For example, comparison of 20-year and 40-year rehabilitation alternatives or comparison of new construction of flexible or rigid pavement alternatives is valid because the alternatives offer equivalent improvements. Comparison of lane replacement versus overlay is also equivalent. Conversely, comparing pavement rehabilitation to new construction, overlay to widening, or rehabilitations at different project locations do not result in equivalent benefits. Projects that provide different benefits should be analyzed using a Benefit-Cost Analysis (BCA), which considers the overall benefits (safety, environmental, social, etc.) of an alternative as well as the costs. For further information on BCA, refer to the Life-Cycle/Benefit-Cost Model (Cal-B/C) user manuals and technical supplements, which are available from the Division of Transportation Planning website at http://www.dot.ca.gov/hq/tpp/tools.html.

2.3.2 Selecting Design Alternatives

Table 1 provides some alternatives that will meet the requirements discussed in Section 2.3.1. To use the table, determine the following information:

1) The pavement project type. Pavement project types are divided into 4 categories: new construction/reconstruction, widening, CAPM, and roadway rehabilitation. The HDM Topic 603 provides definitions for each of the projects.
2) The project document associated with the design phase of project development, such as the Project Initiation Document (PID), the Project Report (PR), or the Project Scope and Summary Report (PSSR). Draft project reports are considered to be the same as project reports.
3) The condition of the project. Conditions are based on the 20-year TI (new construction), existing pavement surface (for widening, rehabilitation, CAPM) and the pavement type and design life selected in the PID.

After obtaining the information identified above, identify the row in Table 1 that best represents the project. The table provides three preferred alternatives (Alternatives 1, 2, and 3) for each condition and some additional alternatives that may be added to (or in some cases substituted for) the three preferred alternatives. Select the alternatives that best suit the project conditions while still meeting the provisions specified in Section 2.3.1. Please note that Table 1 is not a complete list of all possible alternatives for a particular project.

Table 1. Typical Alternatives for Various Types of Projects with Pavement (1)

Pvmt Project Type	Document	Conditions	Alternative 1	Alternative 2	Alternative 3	Other Alternatives that could be considered		
New/ Reconstruction	**PID**	**20-yr Traffic Index (TI_{20})**						
		$TI_{20} > 15$	20-yr Rigid (JPCP)	40-yr Rigid (JPCP)	40-yr Rigid (CRCP)	20-yr Flex(2)	20-yr Composite(3)	40-yr Composite(3)
		$10 < TI_{20} \leq 15$	20-yr Flex(4)	40-yr Rigid (JPCP)	40-yr Flex(4)	40-yr Rigid (CRCP)	20-yr Composite(3)	40-yr Composite(3)
		$TI_{20} \leq 10$	20-yr Flex(4)	40-yr Rigid (JPCP)	40-yr Flex(4)	20-yr Composite(3)	40-yr Composite(3)	
	PR (PA&ED)	**PID Preferred Pvmt Type & Design Life**						
		Flexible (20-yr design)	Flex (HMA)	Flex (RHMA)	Rigid (JPCP)	Flex (HMA w/ OGFC)	Flex (RHMA-G w/ RHMA-O)	Flex (HMA w/ RHMA)
		Flexible (40-yr design)	Flex (HMA w/ OGFC)	Flex (RHMA-G w/ RHMA-O)	Rigid (JPCP)	Flex (HMA w/ RHMA)	Rigid (CRCP)	
		Rigid (20-yr design)	Rigid (JPCP)	Flex (RHMA)	Flex (HMA)			
		Rigid (40-yr design)	Rigid (JPCP)	Rigid (CRCP)(5)	Flex (RHMA w/ RHMA-O)	Composite(3)	Flex (HMA w/ RHMA)	
		Composite (20-yr design)	Composite (HMA)	Composite (RHMA)	Flex (HMA)	Flex (RHMA)	Rigid (JPCP)	Flex (HMA w/ RHMA)
		Composite (40-yr design)	Composite (HMA)	Composite (RHMA)	Rigid (JPCP)	Rigid (CRCP)	Flex (RHMA-G w/ RHMA-O)	Flex (HMA w/ RHMA)
Widening	**PID**	**Existing Road Pvmt Surface**						
		Flexible	RSL Flex	20-yr Flex	40-yr Flex	40-yr Composite(3)	20-yr Composite(3)	
		Rigid	RSL Rigid	RSL Flex	40-yr Rigid			
		Composite(6)	RSL Composite	20-yr Flex	40-yr Composite	20-yr Composite	RSL Flex	
	PR (PA&ED)	**PID Preferred Pvmt Type & Design Life**						
		Flexible (≤ 20-yr design)	HMA	HMA w/ RHMA	RHMA	HMA w/ OGFC	RHMA-G w/ RHMA-O	
		Flexible (> 20-yr design)	HMA w/ RHMA	RHMA-G w/ RHMA-O	HMA w/ OGFC			
		Rigid (≤ 20-yr design)	Rigid	Flex (RHMA)	Flex (HMA)			
		Rigid (> 20-yr design)	Rigid			Flex (RHMA-G w/ RHMA-O)	Flex (HMA w/ OGFC)	
		Composite(6) (≤ 20-yr design)	Composite (HMA)	Composite (RHMA)	Flex (RHMA)	Flex (HMA)	Rigid	
		Composite(6) (> 20-yr design)	Composite (RHMA)	Flex (RHMA-G w/ RHMA-O)	Flex (HMA w/ OGFC)	Composite (HMA)		
CAPM	**PR**	**Existing Road Pvmt Surface**						
		Flexible	HMA	RHMA	HMA w/ RHMA	HMA w/ OGFC	RHMA-G w/ RHMA-O	
		Rigid (< 5% slab replacement)	Grinding (Rigid Strategy)	Thin RHMA Overlay				
		Rigid (≥ 5% slab replacement)	Grind & Slab Replacements	Lane Replacement (Rehab Strategy)				
		Composite(6)	Use Flexible CAPM Alternatives					
Roadway Rehabilitation	**PSSR**	**Existing Road Pvmt Surface**						
		Flexible	HMA	RHMA		HMA w/ OGFC	RHMA-G w/ RHMA-O	
		Flexible w/ OGFC or RHMA-O	HMA w/ OGFC	RHMA-G w/ RHMA-O				
		Rigid	10-yr Crack, Seat & Flex Overlay	20-yr Crack, Seat & Flex Overlay	40-yr Lane Replacement	20-yr Lane Replacement	40-yr Crack, Seat & Flex Overlay(2)	
		Composite(6)	10-yr Overlay	20-yr Overlay	40-yr Lane Replacement	20-yr Lane Replacement		

Flex = Flexible Rehab = Rehabilitation Pvmt = Pavement yr = year

Notes:

(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.

(2) Highway Design Manual (HDM) currently does not provide a methodology for this design. Consult the Office of Pavement Engineering for special design options.

(3) Composite Pvmt may be thin Flex surface (≤ 0.25') over JPCP or CRCP. Choose the same rigid Pvmt type that is being analyzed for one of the other alternatives. Assume RHMA for flexible surface unless it is desired to analyze both RHMA and HMA alternatives or RHMA is not viable (see HDM 631.3)

(4) Assume RHMA unless there are specific reasons RHMA cannot be used. Document these reasons in Project Initiation Documents. If sufficient information is available, can opt to analyze HMA vs. RHMA in addition to rigid pavement alternatives.

(5) Consider only for $TI_{20} \geq 12$.

(6) Includes previously built crack, seat, and flexible overlay projects.

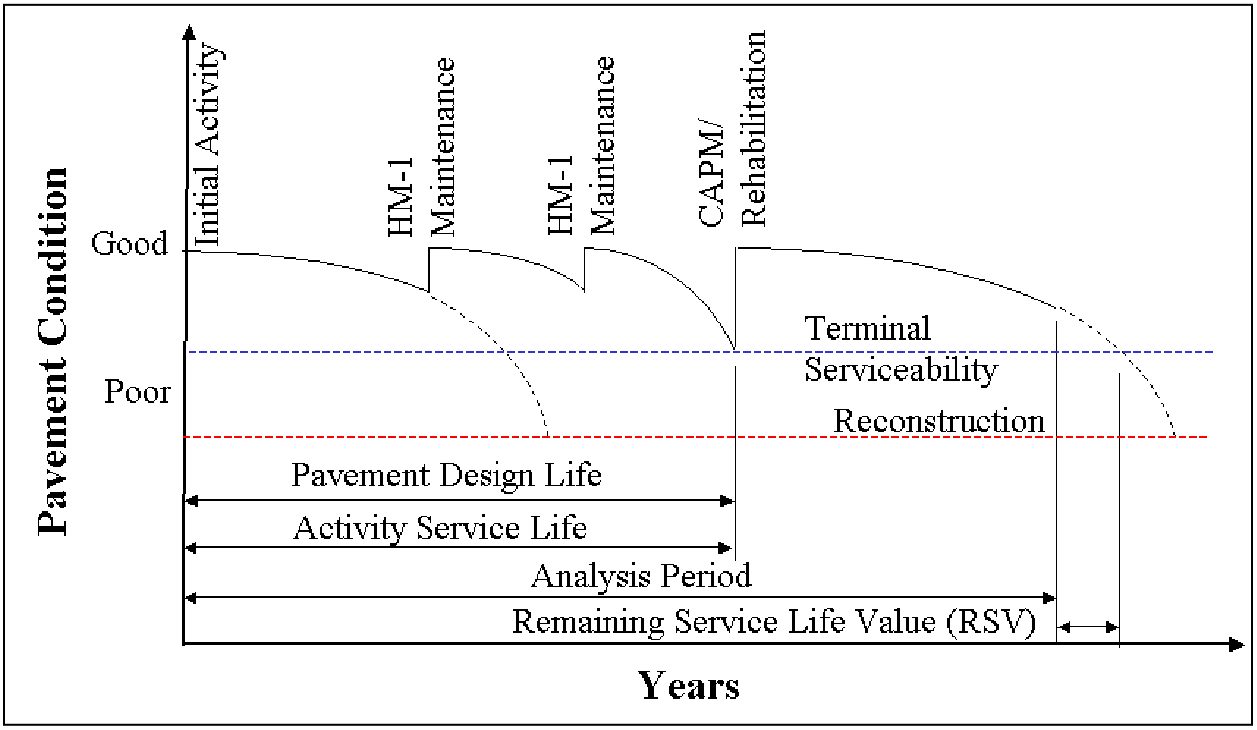
2.4 Analysis Period

The *analysis period* is the period of time during which the initial and any future costs for the project pavement alternatives will be evaluated. Table 2 provides the common analysis periods to be used when comparing alternatives of a given design life or lives. When comparing two or more alternatives, determine the analysis period based on the longest design life. For example, an analysis period of 20 years should be used if CAPM and 20-year design life alternatives are compared; and an analysis period of 55 years if 20-year and 40-year design life are compared.

Alternative Design Life	CAPM	10-Yr	15 or 20-Yr	25 to 40-Yr
CAPM	20 years	20 years	20 years	
10-Yr	20 years	20 years	35 years	55 years
15 or 20-Yr	20 years	35 years	35 years	55 years
25 to 40-Yr		55 years	55 years	55 years

Table 2. LCCA Analysis Periods

LCCA assumes that the pavement will be properly maintained and rehabilitated to carry the projected traffic over the specified analysis period. As the pavement ages, its condition will gradually deteriorate to a point where some type of maintenance or rehabilitation treatment is warranted. Thus, after the initial construction, reasonable maintenance and rehabilitation (M&R) strategies must be established for the analysis period. Figure 2-1 shows the typical relationship between pavement condition and pavement life when appropriate maintenance and rehabilitation strategies are applied in a timely manner.



Note: see Appendix 1, "Glossary and List of Acronyms," for definitions of terms used in the figure.

Figure 2-1: Pavement Condition vs. Years

Additional information about M&R strategies for various types of pavements can be found in Section 2.6, "Maintenance and Rehabilitation Sequences."

2.5 Discount Rate

Discount rate is the interest rate by which future costs (in dollars) will be converted to present value. In other words, it is the percentage by which the cost of future benefits will be reduced to present value (as if the future benefit takes place in the present day). Real discount rates (as opposed to nominal discount rates) reflect only the true time value of money without including the general rate of inflation. Real discount rates typically range from 3% to 5% and represent the prevailing interest of U.S. Government 10-year Treasury Notes. **Caltrans currently uses a discount rate of 4% in the LCCA of pavement structures.**

2.6 Maintenance and Rehabilitation Sequences

After viable project alternatives are identified and the project information is gathered, a pavement M&R schedule for each alternative must be determined. Pavement M&R schedules identify the sequence and timing of future activities that are required to maintain and rehabilitate the pavement over the analysis period. **Pavement M&R schedules found in Appendix 4 of this manual must be used in the LCCA for pavement projects on the State Highway System.** To determine the applicable pavement M&R schedule for a project alternative in Appendix 4, the following information is needed:

1) *Existing/New Pavement Type.* The types are: flexible, rigid, and composite.
2) *Pavement Climate Region.* This is obtained from the map in Figure A4-1, which is also available on the Pavement Engineering website.
3) *Project Type.* The types are: New Construction/Reconstruction, CAPM, and Rehabilitation.
4) *Final Pavement Surface Type.* The final pavement surface type is the pavement alternative being investigated for LCCA. Options include
   - Hot Mix Asphalt (HMA),
   - Hot Mix Asphalt with Open Graded Friction Course (HMA w/ OGFC),
   - Hot Mix Asphalt with Rubberized Hot Mix Asphalt (HMA w/ RHMA),
   - Rubberized Hot Mix Asphalt-Gap Graded (RHMA-G),
   - Rubberized Hot Mix Asphalt-Gap Graded with Rubberized Hot Mix Asphalt-Open Graded (RHMA-G w/ RHMA-O),
   - Jointed Plain Concrete Pavement (JPCP), and
   - Continuously Reinforced Concrete Pavement (CRCP).
5) *Pavement Design Life.* See the HDM Topic 612 for guidance.
6) *Maintenance Service Level (MSL).* MSL is the state highway classification used by the Division of Maintenance for maintenance program purposes. Refer to Appendix 1, “Glossary and List of Acronyms,” for further definition of MSL.

Once all the above information is known, refer to Figure 2-2 to select the appropriate pavement M&R schedule in Appendix 4. Note that table type (F – Flexible, R – Rigid/Composite), climate region and final pavement surface type are shown at the top of each M&R schedule (see Figure 2-3). After selecting the appropriate M&R schedule, select the project type, pavement design life, and Maintenance Service Level (MSL) for the project alternative being considered. Finally, select the alternative that closely matches the project alternative being considered and follow the rehabilitation sequence.

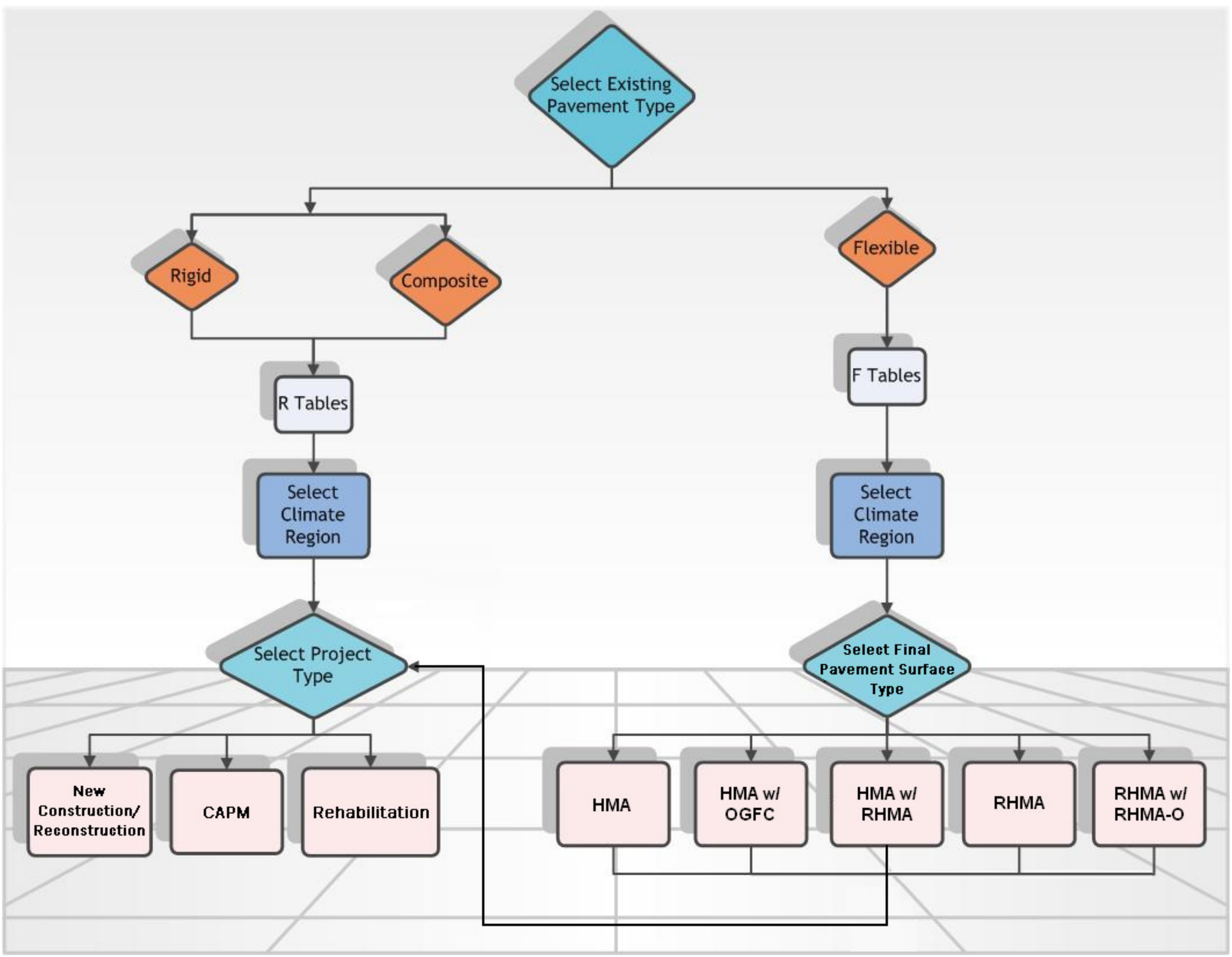


Figure 2-2: Pavement M&R Schedule Determination Flow Chart

Figure 2-3 shows an example of the Pavement M&R Schedules found in Appendix 4 for pavements with RHMA surface type in the State's "coastal" climate region. The M&R schedule tables have been derived from the "Pavement M&R Decision Trees" prepared by each Caltrans district and experience with pavement performance in California (*Note*: these schedules assume there will be no early failures). As shown in the Figure 2-3, the M&R schedules include the initial alternative as well as the future CAPM, rehabilitation, or reconstruction activities and their estimated service lives (see "Activity Service Life (years)" box in Figure 2-3. Interim maintenance treatments such as Major Maintenance (HM-1) projects and work by maintenance field crews performed between each scheduled activity have been converted into an annualized maintenance cost in dollars per lane mile ($/lane-mile).

TABLE F-1 (d)
All Coastal Climate Regions
RUBBERIZED HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5		10		15		20		25		30		35		40		45		50		55	
New Construction/Reconstruction																												
RHMA	20	1,2	Year of Action		0										22		28								50			
			Activity Description		**New / Reconstruct**										CAPM RHMA		Rehab RHMA (20 yr)								CAPM RHMA			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,200									6	900	22	2,500							6	900		
		3	Year of Action		0										22				32				42				51	
			Activity Description		**New / Reconstruct**										CAPM RHMA				CAPM RHMA				CAPM RHMA				Lane Replace (20 yr)	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,200									10	4,100			10	4,000			9	4,400			22	2,200
CAPM																												
RHMA	5+	1,2	Year of Action		0				6																			
			Activity Description		**CAPM RHMA**				Rehab RHMA (20 yr)																			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	6	900			22	2,500																		
		3	Year of Action		0				10																			
			Activity Description		**CAPM RHMA**				CAPM RHMA																			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	4,000			10	4,100																		
Rehabilitation																												
RHMA	20	1,2,3	Year of Action		0								22				28								50			
			Activity Description		**Rehab RHMA (20 yr)**								CAPM RHMA				Rehab RHMA (20 yr)								CAPM RHMA			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,500							6	900			22	2,900							6	900		
			Year of Action		0																							
			Activity Description		**New / Reconstruct**		Select a RHMA schedule for New Construction/Reconstruction from this M&R table																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life																								

Figure 2-3: Example of Pavement M&R Schedule

EAMPLE 2.1

Suppose that one of the alternatives being considered for flexible pavement is a “CAPM HMA w/ RHMA” located in the coastal climate region with a maintenance service level of 2. To determine the appropriate pavement M&R schedule, go to the “F” tables since the existing pavement is a flexible pavement. Since the project is in the coastal region, select the M&R schedules with the heading “All Coastal Regions”. Next, find among the selected schedules the one that addresses the final pavement surface type for the alternative being considered, for this example “Hot Mix Asphalt W/ RHMA”. Thus, the appropriate schedule will have the heading “Table F-1 (c), All Coastal Climate Regions, Hot Mix Asphalt w/ RHMA Pavement Maintenance and Rehabilitation Schedule”. Finally, knowing that the project type is a CAPM and the MSL is 2, we can find the appropriate row and sequence. In this example the sequence is the sixth from the top. From this schedule it can be determined that the HMA w/ RHMA CAPM alternative is expected to last 10 years and the annualized cost for maintenance (HM-1) is estimated at $3,500 per lane-mile. The M&R schedule also calls for a “10-year Rehab HMA w/ RHMA” at year 10 after the implementation of the CAPM alternative. This rehab is expected to last up to 10 years with an annualized maintenance cost of $2,200 per lane-mile.

2.7 Estimating Costs

Life-cycle costs include two types of cost: agency costs and user costs. Agency costs include initial, maintenance, rehabilitation (including CAPM), support, and remaining service life value costs. User costs include the additional travel time and related vehicle operating costs incurred by the traveling public due to potential congestion associated with planned construction throughout the analysis period.

2.7.1 Initial Costs

Initial costs must include estimated construction costs for each alternative to be borne by an agency for implementing a project alternative. The initial construction costs (first activity in the M&R sequence) are determined from the engineer's estimate. Costs for mainline and shoulder pavement, base and subbase, drainage, joint seals, earthwork, traffic control, time-related overhead should be included. The following items are not included:

- Add-on costs such as minor items, supplemental work, mobilization, and contingencies.
- Structure and right of way costs.
- Project support costs for design, environmental, project management, construction administration and inspection, etc.

These above items are not included because their actual costs (at PS&E) between alternatives are typically and shall be assumed to be the same. Construction costs that will not change between alternatives — such as bridges, traffic signage, and striping — may be excluded if those costs can be separated from the rest of the estimate.

The initial costs for each alternative must be estimated to the same level of detail and accuracy for all alternatives. This includes needed items of work which may differ with each alternative. Examples of items that are often overlooked in estimating alternatives, include:

- Costs to replace pavement at transition tapers and to maintain bridge clearance.
- Costs of pre-overlay repairs for overlay strategies such as digouts and slab replacements.
- Cost to shoulder pavement placement/replacement.

See the PDPM for information and work sheets for estimating costs in the PID and the PR.

2.7.2 Maintenance Costs

Maintenance costs include costs for routine, preventive, and corrective maintenance, such as joint and crack sealing, void undersealing, chip seal, patching, spall repair, individual slab replacements, thin HMA overlay, etc., whose purpose is to preserve or extend the service life of a pavement. Caltrans uses the annualized maintenance costs included in the pavement M&R schedules in Appendix 4. These annualized costs are based on the "Pavement M&R Decision Trees" prepared by each Caltrans district and historical cost data collected by the Division of Maintenance.

2.7.3 Rehabilitation Costs

Rehabilitation costs for a particular activity should include costs for project supports and costs for all the necessary appurtenant work for drainage, safety, and other features.

Tables 4 and 5 provide the estimated cost per lane-mile of construction costs (excluding project support costs) for various types of CAPM and rehabilitation projects. These project costs have been summarized from projects funded by Caltrans over the six-year period ending in 2005. After selecting an applicable pavement M&R sequence for the project alternative (as discussed in Section 2.6, "Maintenance and Rehabilitation Sequences"), use the tables to estimate the cost of future rehabilitation activities to be performed after implementing a project alternative. For those future rehabilitation activities whose project type is the same as the proposed project alternative, the user can assume its rehabilitation costs to be the same as the initial costs estimated for the project alternative.

2.7.3.1 Future Project Support Costs

Costs for future project support should be estimated based on the costs identified in the proposed work plan for a project alternative, such as for design, environmental, project management, construction administration and inspection, etc. When work plan data is not yet available, use the agency project support cost multipliers shown in Table 3 with the construction costs to estimate project support costs for a project alternative.

Table 3. Agency Project Support Cost Multipliers*

Type of Project		Range of Project ($)	Multiplier w/ Right-of-Way	Multiplier w/o Right-of-Way
New Construction/ Reconstruction	Small	750,000 - 5,000,000	0.47	0.39
	Medium	5,000,001 - 20,000,000	0.31	0.29
	Large	20,000,001 - 35,000,000	0.25	0.23
	Very Large	35,000,001 - Up	0.24	0.20
Widening	Small	750,000 - 2,500,000	0.56	0.52
	Medium	2,500,001 - 5,000,000	0.39	0.35
	Large	5,000,001 - 15,000,000	0.28	0.26
	Very Large	15,000,001 - Up	0.25	0.24
CAPM	Small	750,000 - 2,000,000	0.19	0.19
	Medium	2,000,001 - 5,000,000	0.18	0.15
	Large	5,000,001 - Up	0.16	0.13
Roadway Rehabilitation	Small	750,000 - 2,000,000	0.35	0.31
	Medium	2,000,001 - 5,000,000	0.28	0.26
	Large	5,000,001 - Up	0.20	0.19

* Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in table.

Example 2.2:

Consider a future HMA overlay CAPM activity with a construction cost estimate of $4.0 million. The corresponding project support cost multipliers in Table 3 for this CAPM activity are 0.18 with right-of-way and 0.15 without right-of-way, respectively. Accordingly, the estimated rehabilitation cost for this activity is $4.72 million ($4.0 million X 1.18 = $4.72 million. $4.0 million for construction and $0.72 million for project supports) with right-of-way acquisition;

Or, $4.6 million ($4.0 million X 1.15 = $4.6 million. $4.0 for construction and $0.6 million for project supports) if the project does not require right-of-way.

Table 4. Estimated Construction Costs of Typical M&R Strategies for Flexible Pavements [1]

Final Surface Type	Pavement Design Life (years)	Future M&R Activity Description	$/Lane-Mile[2]
CAPM			
HMA	5+	Overlay	**99,000**
	5+	Mill & Overlay	**118,000**
HMA w/ OGFC	5+	Overlay	**146,000**
	5+	Mill & Overlay	**165,000**
HMA w/ RHMA	5+	Overlay	**161,000**
	5+	Mill & Overlay	**180,000**
RHMA	5+	Overlay	**100,000**
	5+	Mill & Overlay	**119,000**
RHMA w/ RHMA-O	5+	Overlay	**147,000**
	5+	Mill & Overlay	**162,000**
Rehabilitation			
HMA	10	Overlay	**299,000**
	20		**332,000**
	10	Mill & Overlay	**318,000**
	20		**351,000**
HMA w/ OGFC	10	Overlay	**346,000**
	20		**379,000**
	10	Mill & Overlay	**365,000**
	20		**398,000**
HMA w/ RHMA	10	Overlay	**361,000**
	20		**394,000**
	10	Mill & Overlay	**380,000**
	20		**413,000**
RHMA	10	Overlay	**327,000**
	20		**363,000**
	10	Mill & Overlay	**346,000**
	20		**379,000**
RHMA w/ RHMA-O	10	Overlay	**389,000**
	20		**422,000**
	10	Mill & Overlay	**408,000**
	20		**441,000**
Lane Replacement	**See Table 5b for options**		

Notes:
(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.
(2) Lane-mile construction costs excluding project support costs

Table 5a. Estimated Construction Costs of Typical M&R Strategies for Rigid & Composite Pavements (1)

Final Pavement Type	Pavement Design Life (years)	Future M&R Activity Description	$/Lane-Mile(5)
CAPM			
Flexible / Composite	5+	Flexible Overlay	**81,000**
		Flexible Overlay w/ JPCP Slab Replacements (**FO + JPCP SR**, RSC 12-Hour Curing Time)	**84,000**
		Flexible Overlay w/ JPCP Slab Replacements (**FO + JPCP SR**, RSC 4-Hour Curing Time)	**91,000**
Rigid - Jointed Plain Concrete Pavement (JPCP)	5+	Concrete Pavement Rehab A(2) (with RSC of 12-Hour Curing Time)	**123,000**
		Concrete Pavement Rehab A(2) (with RSC of 4-Hour Curing Time)	**148,000**
	5+	Concrete Pavement Rehab B(3) (with RSC of 12-Hour Curing Time)	**88,000**
		Concrete Pavement Rehab B(3) (with RSC of 4-Hour Curing Time)	**106,000**
	5 +/-	Concrete Pavement Rehab C(4) (with RSC of 12-Hour Curing Time)	**82,000**
		Concrete Pavement Rehab C(4) (with RSC of 4-Hour Curing Time)	**89,000**
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	5+	Punchout Repairs A(7) (with RSC of 12-Hour Curing Time)	**163,000**
		Punchout Repairs A(7) (with RSC of 4-Hour Curing Time)	**175,000**
	5+	Punchout Repairs B(8) (with RSC of 12-Hour Curing Time)	**136,000**
		Punchout Repairs B(8) (with RSC of 4-Hour Curing Time)	**147,000**
	5 +/-	Punchout Repairs C(9) (with RSC of 12-Hour Curing Time)	**20,000**
		Punchout Repairs C(9) (with RSC of 4-Hour Curing Time)	**25,000**

Notes:

(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.

(2) Concrete Pavement Rehab A involves pavement grinding, significant slab replacement, spall repair, & joint seal repair.
It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is greater than or equal to 5% and less than or equal to 7%.
For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(3) Concrete Pavement Rehab B involves pavement grinding, moderate slab replacement, spall repair, & joint seal repair.
It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2 and 5%.

(4) Concrete Pavement Rehab C involves pavement grinding, minor slab replacement, spall repair, & joint seal repair.
It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2% or less.
For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(5) Lane-mile construction costs excluding project support costs.

(6) Costs for terminal joint at $9,000 per lane should be applied in addition to lane replacement cost.
Lane replacement costs are per lane-mile and terminal joint cost are per lane.

(7) Punchout Repair A involves **significant** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced Concrete pavements that had previous punchout repairs and a flexible overlay.

(8) Punchout Repair B involves **moderate** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced Concrete pavements where the total number of current and previous punchout repairs exceed 4 per mile.

(9) Punchout Repair C involves **minor** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced Concrete pavements where the total number of current and previous punchout repairs do not exceed 4 per mile.

Table 5b. Estimated Construction Costs of Typical M&R Strategies for Rigid & Composite Pavements [(1)]

Final Pavement Type	Pavement Design Life (years)	Future M&R Activity Description	$/Lane-Mile[(5)]
Rehabilitation			
Flexible / Composite	10	Flexible Overlay w/ Slab Replacements (**FO+JPCP SR**, **RSC of 12-Hour Curing Time**)	**215,000**
		Flexible Overlay w/ Slab Replacements (**FO+JPCP SR**, **RSC of 4-Hour Curing Time**)	**233,000**
	10	Mill, Slab Replacement & Overlay (**MSRO, RSC of 12-Hour Curing Time**)	**234,000**
		Mill, Slab Replacement & Overlay (**MSRO, RSC of 4-Hour Curing Time**)	**252,000**
	20	Mill, Slab Replacement & Overlay (**MSRO, RSC of 12-Hour Curing Time**)	**260,000**
		Mill, Slab Replacement & Overlay (**MSRO, RSC of 4-Hour Curing Time**)	**280,000**
	10	Crack, Seat, & Flexible Overlay **(CSFOL)**	**251,000**
	20		**279,000**
	20	Lane Replacement with Flexible	**941,000**
	40		**1,255,000**
	20	Lane Replacement with composite (with RSC of 12-Hour Curing Time)	**2,011,000**
	40		**2,349,000**
	20	Lane Replacement with composite (with RSC of 4-Hour Curing Time)	**2,482,000**
	40		**2,821,000**
Rigid - Jointed Plain Concrete Pavement (JPCP)	20	Lane Replacement (with RSC of 12-Hour Curing Time)	**1,493,000**
	40		**1,752,000**
	20	Lane Replacement (with RSC of 4-Hour Curing Time)	**1,854,000**
	40		**2,113,000**
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	20	Lane Replacement (with RSC of 12-Hour Curing Time)	**1,951,000**
	40		**2,289,000**
	20	Lane Replacement (with RSC of 4-Hour Curing Time)	**2,422,000**
	40		**2,761,000**

Notes:

See Table 5a.

The following steps describe how the construction costs in Tables 4, 5a, or 5b can be used to estimate the costs of future rehabilitation activities:

1) Find the applicable pavement M&R schedule for the project alternative being considered (as described in Section 2.4).
2) Using the M&R schedule found in step1, identify the sequence of future rehabilitation activities that will take place through the entire analysis period.
3) Find the description that best fits each future rehabilitation activities shown in the M&R schedule sequence by selecting the appropriate project type, the final pavement surface type, the design life, and the future M&R activity in Tables 4, 5a, or 5b (Note: in most cases there will be more than one choice that will require exploration).
4) Determine the applicable lane-mile cost for each future rehabilitation activity from Tables 4, 5a, or 5b.
5) Determine the total construction cost for each of the future rehabilitation activity as follows:
    (a) Multiply the total project lane-miles by the lane-mile cost found in step 4 to get the construction cost for the future rehabilitation activity;
    (b) Determine the project support cost multiplier that is applicable to the calculated construction cost from Table 3;
    (c) Determine the project support cost for the future rehabilitation activity by multiplying the calculated construction cost by the project support cost multiplier;
    (d) Add the construction cost found in (a) and the support cost found in (c) to determine the total construction cost ("Agency Construction Cost").

Example 2.3:

Determine the cost for future rehabilitation activities which will occur after implementing the project alternative described below:

CAPM w/o right-of-way acquisition (HMA Overlay)

- *40.0 lane-miles (i.e., total project lane-miles including turn, auxiliary lane-miles) of an existing flexible pavement*
- *Initial Agency Construction Cost: $4.6 million ($4.0 million for construction and $0.6 million for project support)*
- *Analysis Period: 20 years.*
- *Climate: Coastal*
- *Maintenance Service Level: 1*

Solution:

1) *Find the applicable pavement M&R schedule (from Appendix 4, Table F-1)*

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5		10		15	
CAPM												
HMA	5+	1,2	Year of Action		0		5				15	
			Activity Description		**CAPM HMA**		Rehab HMA (10 yr)				CAPM HMA	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile)	5	1,100	10	6,100			5	1,100
		3	Year of Action		0				10			
			Activity Description		**CAPM HMA**				CAPM HMA			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile)	10	6,200			10	6,100		

2) *Identify the prescribed sequence of future rehabilitation activities after initial construction (within the 20-year analysis period)*

   (a) *10-year Rehab HMA in Year 5*

   (b) *CAPM in Year 15*

3) *Applicable M&R alternative for each future rehabilitation activity (from Table 4)*

   (Note: solution shows that after initial construction the engineer will have a choice of future rehabilitation activities. The solution for both is shown below)

(a) 10-year Rehab HMA in Year 5:

- *HMA Overlay*
- *HMA Mill and Overlay*

(b) CAPM in Year 15:

- *HMA Overlay*
- *HMA Mill and Overlay*

4) Lane-mile costs of future rehabilitation activities (from Table 4)

(a) 10-year Rehab in Year 5:

- *HMA Overlay = $299,000/lane-mile*
- *HMA Mill and Overlay = $318,000/lane-mile*

(b) CAPM in Year 15: not applicable [Note: it is assumed that the rehabilitation costs would be same as the agency construction cost for the initial construction ($4,000K)]

- *HMA Overlay = Assume same as initial agency construction cost ($4 million)*
- *HMA Mill and Overlay $118,000/lane-mile*

5) Construction costs for future rehabilitation activities

(a) 10-year Rehab in Year 5:

- *HMA Overlay = $299,000/lane-mile X 40 = $11,960,000*
- *HMA Mill and Overlay = $318,000/lane-mile X 40 = $12,720,000*

(b) 5-year CAPM in Year 15:

- *HMA Overlay = $4,000,000*
- *HMA Mill and Overlay = $118,000/lane-mile X 40 = $4,720,000*

6) Project support cost multipliers for future rehabilitation activities (from Table 3)

(a) 10-year Rehab in Year 5:

- *0.19 (for rehabilitations over $5 million w/o right-of-way)*

(b) 5-year CAPM in Year 15:

- *0.15 (for CAPM's over $2 million w/o right-of-way)*

7) Project support costs for future rehabilitation activities

(a) 10-year Rehab in Year 5:

- *HMA Overlay = $11,960,000 X 0.19 = $2,272,400*
- *HMA Mill and Overlay = $12,720,000 X 0.19 = $2,416,800*

(b) CAPM in Year 15: $600K

- *HMA Overlay = $4,000,000 X 0.15 = $600,000*
- *HMA Mill and Overlay = $4,720,000 X 0.15 = $708,000*

8) *Agency construction costs & agency maintenance costs for the initial construction and future rehabilitation activities*

   (a) *CAPM Initial Construction (Year 0):*
   - *Agency Construction Cost : 4,600,000 ($4,000K + $600K) [given]*
   - *Agency Maintenance Cost: $1,100/lane-mile x 40 lane-miles = $44,000*

   (b) *10-year Rehab in Year 5:*
   - *Agency Construction Cost:*
     - *HMA overlay = $11,960,000 + $2,272,000 = $14,232,000*
     - *HMA Mill & Overlay = $12,720,000 + $2,416,800 = $15,136,800*
   - *Agency Maintenance Cost: $6,100/lane-mile x 40 lane-miles = $244,000*

   (c) *CAPM in Year 15:*
   - *Agency Construction Cost*
     - *HMA Overlay = Same as CAPM in Year 0 = 4,600,000 ($4,000K + $600K)*
     - *HMA Mill & Overlay = $4,720,000 + $708,000 = $5,428,000*
   - *Agency Maintenance Cost: $1,100/lane-mile x 40 lane-miles = $44,000*

2.7.4 User Costs

Best-practice LCCA calls for consideration of not only agency costs, but also costs to facility users. *User costs* include travel time costs and vehicle operating costs (excluding routine maintenance) incurred by the traveling public. User costs arise when work zones restrict the normal flow of the facility and increase the travel time of the user by generating queues or formal or informal detours. User costs are also incurred during normal operations, but they are not considered in LCCA because normal travel costs are not dependent on individual project alternatives. Additional user costs resulting from work zones can become a significant factor when a large queue occurs in a given alternative.

2.7.5 Remaining Service Life Value

If an activity has a service life that exceeds the Analysis period (AP), the difference is known as the *Remaining Service Life Value* (RSV). Any rehabilitation activities (including the initial construction), except for the last rehabilitation activity within the AP, will not have a RSV. The RSV of a project alternative at the end of the analysis period is calculated by prorating the total construction cost (agency and user costs) of the last scheduled rehabilitation activity.

2.8 Calculating Life-Cycle Costs

Calculating life-cycle costs involves direct comparison of the total life-cycle costs of each alternative. However, dollars spent at different times have different present values, the anticipated costs of future rehabilitation activities for each alternative need to be converted to their value at a common point in time. This is an economic concept known as "discounting."

A number of techniques based upon the concept of discounting are available. FHWA recommends the present value (PV) approach, which brings initial and future costs to a single point in time, usually the present or the time of the first cost outlay. The equation to discount future costs to PV is:

$$PV = F\frac{1}{(1+i)^n} \qquad \text{(Equation 1)}$$

Where $\boldsymbol{F}$ = future cost at the end of nth years

$\boldsymbol{i}$ = discount rate

$\boldsymbol{n}$ = number of years

However, the equivalent uniform annual cost (EUAC) approach is also used nationally. It produces the yearly costs of an alternative as if they occurred uniformly throughout the analysis period. The PV of this stream of EUAC is the same as the PV of the actual cost stream. Whether

PV or EUAC is used, the decision supported by the analysis will be same. **Caltrans requires the LCCA results to be documented using the present value approach.**

CHAPTER 3 - USING *REALCOST*

3.1 Methodology

1. Gather project information:

   Gather as much project information as possible, such as:

   - Existing pavement type
   - Remaining service life of existing pavement (for widening)
   - Project location
   - Project climate region
   - Project scope
   - Potential final pavement surface type & project type
   - Maintenance Service Level (MSL)
   - Expected construction year
   - Construction scheme such as staging, direction, construction windows, etc.
   - Traffic information

2. Select design alternatives.

   Use the suggested alternatives in Table 1 or the preferred methodology recommended by your district for selecting design alternatives. However, selection of project alternatives must follow the requirements specified in Section 2.3 of this manual.

   After selecting the competing alternatives, determine the pavement structure associated with their design lives. Then, estimate the costs associated with each of the alternatives (Engineer's estimate).

3. Determine the "Analysis Period."

   Once the alternatives are selected, use Table 2 (see Section 2.4) to determine the appropriate analysis period. **When comparing three or more alternatives, determine the analysis period using the longest design life.**

4. Determine the traffic data inputs.

   - AADT for construction year
   - Single Unit truck percentage
   - Combination Trucks percentage
   - Normal operating speed for the project location
   - Number of lanes open under normal conditions. Section 3.3.3 of this manual shows how to obtain the information required to determine this input.

5. Determine the traffic flow information.

   Use Table 6 to determine the traffic flow inputs for *RealCost*. Traffic flow inputs include:

   - Maximum AADT total for both traffic directions
   - Free Flow Capacity of the facility
   - Queue Dissipation Capacity of Work Zone
   - Expected maximum queue length,

6. Enter the "Project-Level Inputs" into *RealCost*.

7. Determine the future rehabilitation sequence.

   For each alternative, select the appropriate M&R schedule from Appendix 4. Section 2.6 shows the process for selecting the M&R Schedule and determining the future rehabilitation sequence.

8. Determine the future rehabilitation cost.

   There is a cost associated with each of the future rehabilitation activities in the sequence. See Section 2.7 for information on how to determine these costs.

9. Determine the "Agency Maintenance Cost" from the appropriate M&R table.

10. Determine the "Work Zone Duration."

11. For each of the alternatives, determine the Work Zone Duration (WZD) for each future rehabilitation activity in the sequence. Use Table 8 or 9 as shown in this chapter.

12. Enter the "Alternative-Level Inputs."

13. Evaluate the results.

Note that if the project is evaluating more than two alternatives, a separate accounting of *RealCost* will need to be developed in order to compare all the alternatives.

3.2 Installing & Starting *RealCost*

3.2.1 Installation

In order to prepare a life-cycle cost estimate using *RealCost* (Version 2.2.1 California Edition), the software must first be installed. The software can be downloaded from: http://www.dot.ca.gov/hq/esc/Translab/OPD/DivisionofDesign-LCCA.htm. Follow the installation instructions provided on the website.

> ***Note:***
> *Because RealCost is an add-on program designed to run in Microsoft Excel 2000 (or later), it should not require installation by Caltrans' IT staff.*

3.2.2 Start Up

Select "*RealCost* 2.2" from the Windows "Start Menu" (Programs > *RealCost* > *RealCost* 2.2) to launch the program.

When prompted by Excel, choose "Enable Macros" to run *RealCost.* Immediately after the worksheet appears, the "Switchboard" panel opens on top of it (see Figure 3-1). If the switchboard does not appear, go to the "Tools" drop down menu, select "Macro," and change the security to medium.

> ***Note:***
> *The program allows you to input data either through the "Switchboard" or directly into the Input Worksheet. This manual contains instructions for entering information by using the "Switchboard". To input values directly into the Input Worksheet, close the "Switchboard" by clicking the "X" in the upper right-hand corner. To restore it later, click "RealCost" drop down menu at the top of the Excel window, and select "RealCost Switchboard."*

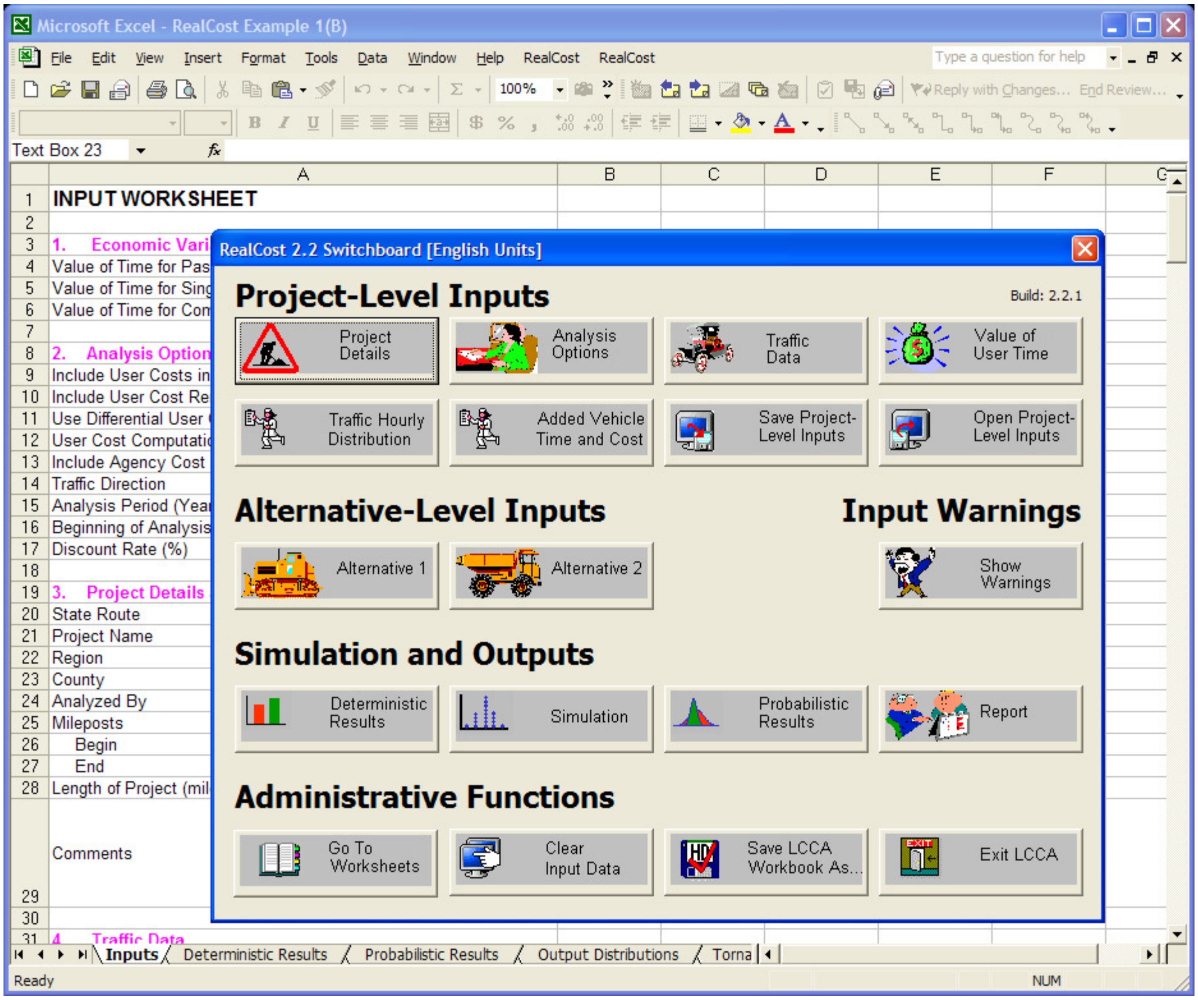


Figure 3-1: *RealCost* Switchboard

The "Switchboard" consists of five sections (See Figure 3-1):

- Project-Level Inputs;
- Alternative-Level Inputs;
- Input Warnings;
- Simulation and Outputs;
- Administrative Functions.

These items are discussed in Sections 3.3 through Section 3.6

Note:

Most of the functions available from the "Switchboard" are also accessible by selecting the "RealCost" drop down menu in the Microsoft Excel menu bar.

3.3 Project Inputs

RealCost requires two levels of information. The first, "**Project-Level Inputs**," which are discussed in Sections 3.3.1 to 3.3.7, are project-level data that apply to all the alternatives being considered for the project. The second information level, "**Alternative-Level Inputs**" (discussed in Section 3.3.8), are data that defines the differences between project alternatives (e.g., agency costs and work zone specifics for each alternative's component activities). To emphasize the differences between the two types of inputs, *RealCost* requires that they are entered separately.

3.3.1 Project Details

The "Project Details" panel (Figure 3-2) is used to enter the project information details. Note that other than the "Mileposts," information entered here will not be used in the analysis. The information entered in here is used to identify and differentiate between projects. Once all the project documentation details are entered, click the "Ok" button to return to the "Switchboard" or the "Cancel" button to start over.

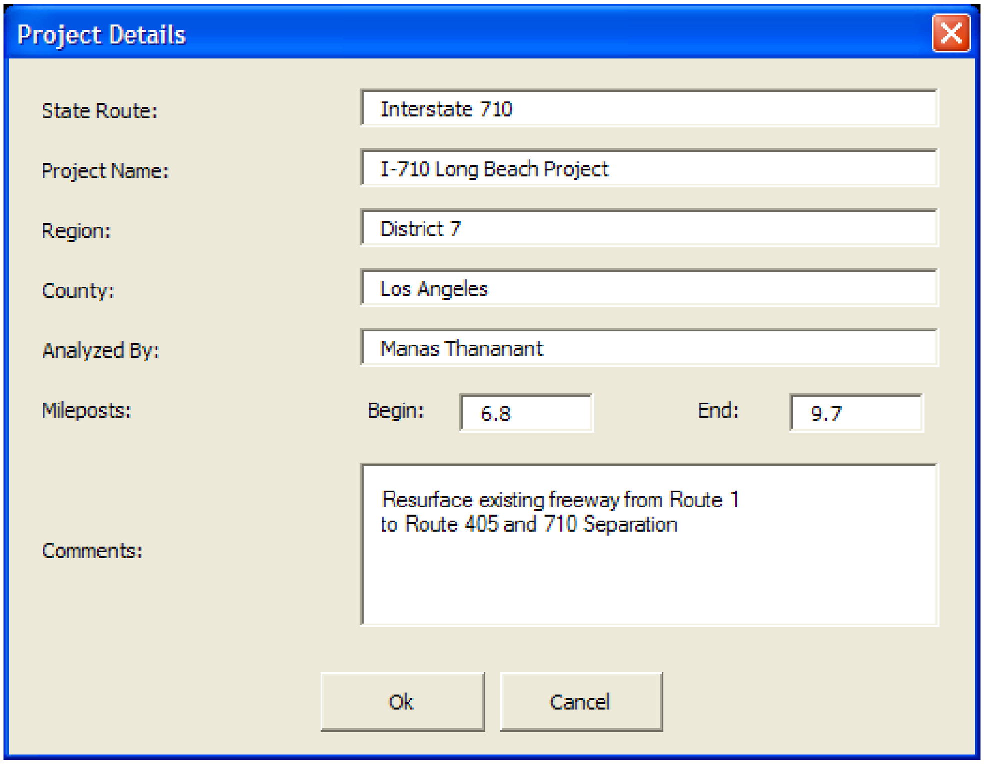


Figure 3-2: Project Details Panel

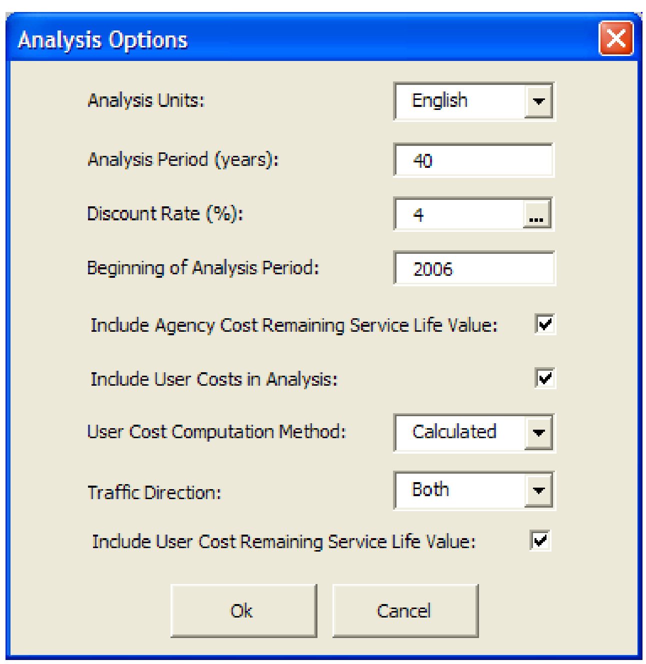


Figure 3-3: Analysis Options Panel

3.3.2 Analysis Options

The "Analysis Options" panel (Figure 3-3) is used to define the user limits that will actually be applied in the analysis of the project alternatives. This panel is where the actual analysis input for the project begins. The data inputs and analysis options available on this Panel are detailed below.

- _Analysis Units_: Select either "English" or "Metric" to set the units to be used in the analysis.
- _Analysis Periods (years)_: Enter an analysis period (in years) during which project alternatives will be compared.
- _Discount Rate (%)_: Enter the Caltrans default value of 4 percent for deterministic analysis.
- _Beginning of Analysis Period_: Enter the year in which construction of the project alternative is expected to begin. This is the same as the construction year ADT found in the design designation or traffic projections for the project (see Figure 3-4 from HDM Index 103.1). This should be the same year as the initial construction year AADT from the design designation. If the project did not require a design designation (i.e. traffic projections) or traffic projections were not done, use the year you expect the project will begin construction.

ADT (2000) = 9800	D = 60%
ADT (2020) = 20 000	T = 12%
DHV = 3000	V = 70 mph
ESAL = 4 500 000	TI_{20} = 11.0

Figure 3-4: Design Designation

- _Include Agency Cost Remaining Service Life Value_: Select the checkbox for *RealCost* to automatically calculate and include the prorated share of the agency cost of the last future rehabilitation activity if it extends beyond the analysis period.

- *Include User Costs in Analysis*: Select the checkbox to have *RealCost* include user costs (see Section 2.5) in the analysis and display the calculated user costs results.
- *User Cost Computation Method*: Select "Calculated" to have *RealCost* calculate user costs based on project-specific input data.

> ***Note:***
>
> *As an option, CA4PRS can be used to calculate the user costs for the life-cycle cost analysis. CA4PRS (Rapid Rehab Software) is software developed by Caltrans and others to compare the impacts on construction schedules and the traveling public of various traffic management alternatives. One of the outputs from the program is user costs. The program is currently limited on what options it can investigate but is being expanded as resources allow. The latest version of CA4PRS and the user manual can be obtained from the Division of Research and Innovation website at:*
>
> *http://www.dot.ca.gov/research/roadway/ca4prs/ca4prs.htm*
>
> *If CA4PRS data is used, analyses will be needed for all of the initial construction options and future rehabilitation options. If CA4PRS generated data is used, select "Specified" under "User Cost Computation Method".*

- *Traffic Direction*: Directs *RealCost* to calculate user costs for the "Inbound" lanes, the "Outbound" lanes, or "Both" lanes. Select the traffic direction that will be affected by work zone operations. "Inbound" is used for the direction where traffic peaks in the AM hours. "Outbound" is used for the direction where traffic peaks in the PM hours. "Both" is used when construction is occurring in both directions.
- *User Cost Remaining Service Life Value (RSLV)*: Select the checkbox to have *RealCost* include the user RSLV of a project alternative. Once all the analysis options are defined, click the "Ok" button to return to the "Switchboard".

3.3.3 Traffic Data

The "Traffic Data" panel (Figure 3-5) is used to enter project-specific traffic data that will be used exclusively to calculate work zone user costs in accordance with the method outlined in the FHWA's *LCCA Technical Bulletin* (1998) and "Life-Cycle Cost Analysis in Pavement Design."

Traffic data are developed for PIDs and PRs when pavement work is involved. Some of the data for the "Traffic Data" panel can be found in the design designation (Figure 3-4), traffic projections generated for the specific project, or from the Division of Traffic Operations website (http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm).

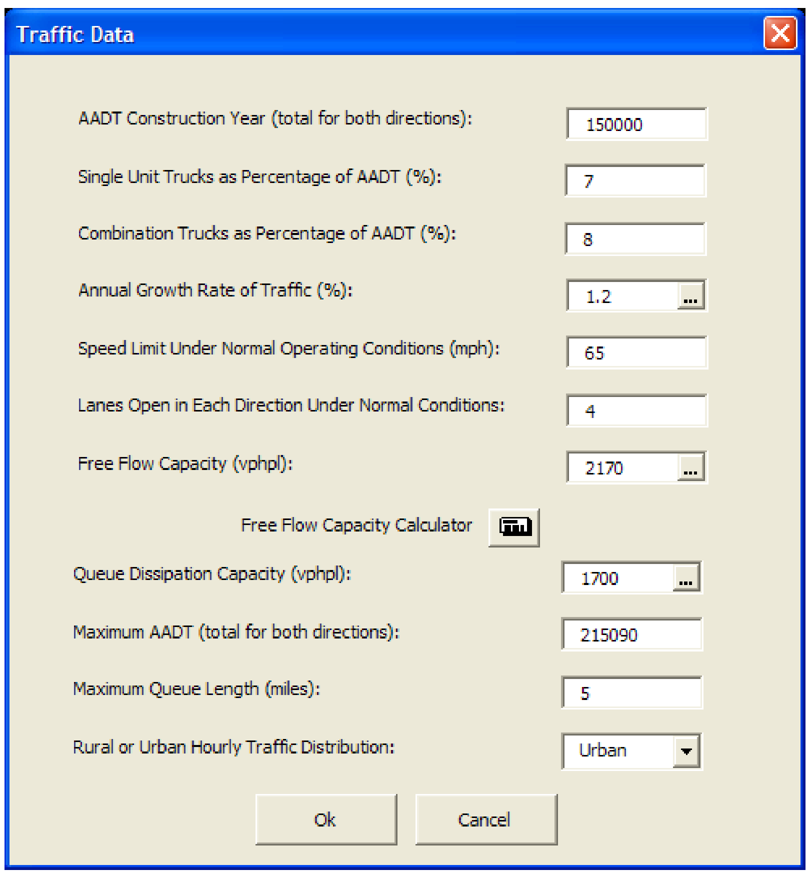


Figure 3-5: Traffic Data Panel

- *<u>AADT Construction Year (total for both directions)</u>*: Enter the annual average daily traffic (AADT) total for both directions in the beginning year of the analysis. This is the same as the construction year ADT found in the design designation or traffic projections for the project (see HDM Index 103.1 and Figure 3-4). For an example of what to do if a design designation or traffic forecast was not developed for the project, see Appendix 6.

- *Single Unit Trucks as Percentage of AADT (%)*: Enter the percentage of the AADT that is single unit trucks (i.e., commercial trucks with two-axles and four tires or more) by doing the following:

									TRUCK AADT TOTAL By Axle				% TRUCK AADT By Axle					
RTE	DIST	CNTY	POST MILE	LEG	DESCRIPTION	VEHICLE AADT TOTAL	TRUCK AADT TOTAL	TRUCK % TOT VEH	2	3	4	5+	2	3	4	5+	EAL 1-WAY (1000)	YEAR VER/ EST
001	12	ORA	R.129	A	DANA POINT, JCT. RTE. 5	38500	2395	6.22	813	1133	321	128	33.93	47.32	13.39	5.36	224	03E
001	12	ORA	R.78	A	DANA POINT, DOHENY PARK ROAD	48500	2362	4.87	801	1118	316	127	33.93	47.32	13.39	5.36	221	03E
001	12	ORA	9.418	B	LAGUNA BEACH, JCT. RTE. 133 NORTH	40000	696	1.74	272	320	64	40	39.08	45.98	9.2	5.75	62	03E
001	12	ORA	9.418	A	LAGUNA BEACH, JCT.	43500	757	1.74	296	348	70	44	39.08	45.98	9.2	5.75	68	03E

Figure 3-6: Traffic Information

Go to the Division of Traffic Operations Traffic Data Branch website (***http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm***) and find the most current file of "Annual Average Daily Truck Traffic" data available (see Figure 3-6).

Find the "% Truck AADT" for 2-axle trucks (TA) at the project location. There may be several values given within the limits of the project. Choose the one that best represents the overall project, use the average or the weighted average.

Then, obtain the truck traffic volume (T) from the design designation (HDM Topic 103.1, Figure 3-4). This value is measured as a percentage. If there is no design designation, use the Total Trucks % value from the Division of Traffic Operations web site referred to above (Use selection process similar to the one used for 2-axle truck).

Note:

The total truck volume in the design designation does not need to match the total truck percentage on the Division of Traffic Operations website. If there is a wide disparity in values between the two numbers, the designer should review the accuracy of the traffic projections in the design designation and have the design designation updated if necessary.

Use Equation 2 to calculate the "Single Unit Trucks as Percentage of AADT (%)" (Assumption: "Total Trucks %" and "Single Unit Trucks %" will remain the same in future years):

$$SUT = T \times (\frac{TA}{100}) \qquad \text{(Equation 2)}$$

Where

SUT = Single Unit Trucks as Percentage of AADT (%)

T = Truck Traffic Volume (% of AADT Total)

TA = 2-Axle Percent (percentage of Truck AADT Total)

Example 3.1:

Given:

Total Trucks % = 6.22 %

2-Axle Percent = 33.93 %

Find:

The Single Unit Trucks as Percentage of AADT

Using Equation 2, the Single Unit Trucks as Percentage of AADT (%) is

$6.22 \times (\frac{33.93}{100}) = 2.11\ \%$ *(or 2.1, but be consistent)*

- *Combination Trucks as Percentage of AADT (%)*: Enter the percentage of the AADT that is combination trucks (i.e., trucks with three axles or more). This value is obtained by subtracting the "Single Unit Trucks as Percentage of AADT (%)" (SUT) from the "Total Trucks % (percentage of AADT Total)" (T).
- *Annual Growth Rate of Traffic (%)*: Enter the percentage by which the AADT in both directions will increase each year. Contact the Division of Transportation System Information for the "Annual Growth Rate of Traffic" or calculate the approximate value with the available AADT values (in the most current and future years) using the following equation:

$$A = [(\frac{FT}{MT})^{(\frac{1}{FY-MY})} - 1] \times 100 \qquad \text{(Equation 3)}$$

Where

A = Annual Growth Rate of Traffic (%)

FT = Future Year AADT (total for both directions) obtained from the project design designation (HDM 103.1)

MT = Most Current Year AADT (total for both directions) obtained from the project design designation (HDM 103.1)

FY = Future Year in which AADT is available

MY = Most Current Year in which AADT is available.

Example3.2:

Given:

Future Year AADT (total for both directions) = 18,000 (year 2025)

Most Current Year AADT (total for both directions) = 9,800 (year 2005)

The Annual Growth Rate of Traffic is:

$$[(\frac{18{,}000}{9{,}800})^{(\frac{1}{2025-2005})} - 1] \times 100 = 3.09\%$$

- *Speed Limit under Normal Operating Conditions (mph)*: Enter the posted speed limit at the project location. If a roadway is being newly built, enter an anticipated speed limit based on traffic laws. District Traffic Operations can provide a recommendation if needed.
- *Lanes Open in Each Direction under Normal Conditions*: Enter the number of lanes open to traffic in each direction under normal operating conditions of the facility. For new construction and/or widening of an existing roadway, enter the number of lanes[1] that will open after completing the initial construction.
- *Free Flow Capacity (vphpl)*: Enter the number of vehicles per hour per lane (vphpl) under normal operating conditions. Table 6 provides typical values for standard lane and shoulder widths for various types of terrain. If there are nonstandard lane and shoulder widths or if it is desired to get a more specific free flow capacity, click the "Free Flow Capacity Calculator" in *RealCost* (see Figure 3-5) to open a panel that calculates free flow capacities based upon the Highway Capacity Manual (1994, 3rd Ed.). To use the calculator, the following project-specific information is needed: number of lanes in each direction, lane width, proportion of trucks and buses (for state highways use % of trucks only), upgrade, upgrade length (for multiple slopes use the average grade throughout the project), obstruction on two sides, and distance to obstruction/shoulder width (Where the existing shoulder width is unknown, use the standard shoulder width as the input).

> ***Note:***
> *An alternate procedure for estimating "Free Flow Capacity" can be found in Appendix 5.*

[1] Using the ultimate lane configuration and entering a "Work Zone Duration" ("Alternative 1," Figure 3-10) of zero for the initial construction of each new construction or widening alternative will generate acceptable results of the analysis of future rehabilitation activities.

Table 6. Traffic Input Values [1,2]

Type of Terrain	Level	Rolling	Mountainous	Level	Rolling	Mountainous
Free Flow Capacity (vphpl)	1,620	1,480	1,260	2,170	1,950	1,620
Queue Dissipation Capacity (vphpl)	1,710	1,570	1,330	1,700	1,530	1,270
Maximum AADT **Per** Lane	40,955	37,390	31,850	53,773	48,305	40,140
Work Zone Capacity (vphpl)[3]	1,050	960	820	1,510	1,360	1,130
Maximum Queue Length	7.0 miles if the estimated maximum queue length is longer than 7.0 miles			5.0 miles if the estimated maximum queue length is longer than 5.0 miles		

Notes:
(1) Derived from Highway Capacity Manual 2000.
(2) Refer to the calculation procedures included in Appendix 5, "Traffic Inputs Estimation".
(3) Assumed one lane to be open for traffic in single-lane highways and two or more lanes to be open for traffic in multi-lane highways.

- *Queue Dissipation Capacity (vphpl)*: Enter the vehicles per hour per lane capacity of each lane during queue-dissipation operating conditions. Table 6 provides values for typical two-lane and multi-lane (in each direction) highways. As an alternative, estimate the queue dissipation capacity using the procedures for "Queue Dissipation Capacity" in Appendix 5.
- *Maximum AADT (total for both directions)*: Enter the maximum AADT (total for both directions) at which the traffic growth will be capped. This value recognizes that there is only so much traffic that can be placed on a roadway in a 24-hour period. Table 6 provides recommended per lane values for typical two-lane and multi-lane highways, multiple the value by the total number of lanes for both directions to obtain the Maximum AADT. As an alternative, the volume may be estimated using the procedures for "Maximum AADT" in Appendix 5.
- *Maximum Queue Length (miles)*: Enter a practical maximum length of queue in miles. Reasonable maximum queue length could be one or two exits prior to the work zone or an exit that leads to a reasonable alternate route. Queue-related user costs, which are

based upon queue length, will be calculated with this value in cases when the *RealCost*-calculated queue lengths exceed this value. If a project-specific value is not available, enter seven (7) miles for two-lane highways and five (5) miles for multi-lane highways respectively as shown in Table 6.

> ***Note:***
> *Appendix 5 provides an explanation on the demand-capacity model – queuing theory – that RealCost uses in calculating maximum queue length.*

- *Rural or Urban Hourly Traffic Distribution*: Select "Rural" or "Urban" depending on the project location. For details on the classification system of both urban and rural roads, visit the Division of Transportation System Information website at: http://www.dot.ca.gov/hq/tsip/hseb/func_clas.html and http://www.dot.ca.gov/hq/tsip/hseb/crs_maps/

Once all the traffic data has been input, click the "Ok" button to return to the Switchboard or the "Cancel" button to start over.

3.3.4 Value of User Time

The "Value of User Time" panel (Figure 3-7) is used to enter the estimated cost applied to an hour of user time. The dollar value of user time can be different for each type of vehicle and is used to calculate user costs associated with delay during work zone operations. Enter the following values:

- $11.51 per hour for passenger cars.
- $27.83 per hour for single unit trucks.
- $27.83 per hour for combination trucks.

These dollar values are based on Caltrans' Division of Traffic Operations Memorandum to District Deputy Directors dated March 3rd, 2006. Once the dollar values have been entered, click the "Ok" button to return to the "Switchboard" or click the "Cancel" button to start over.

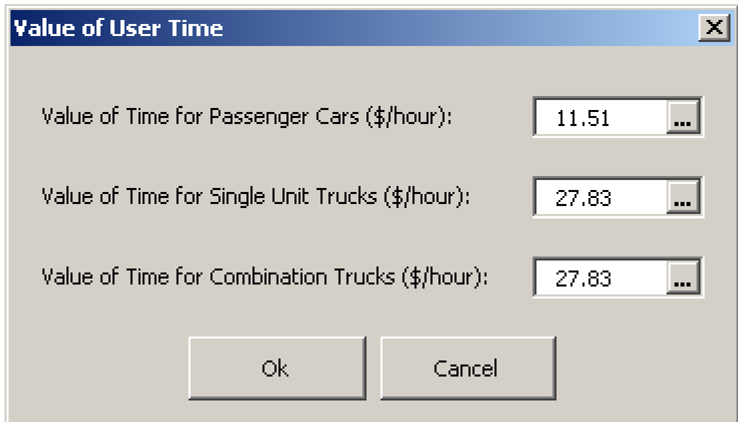
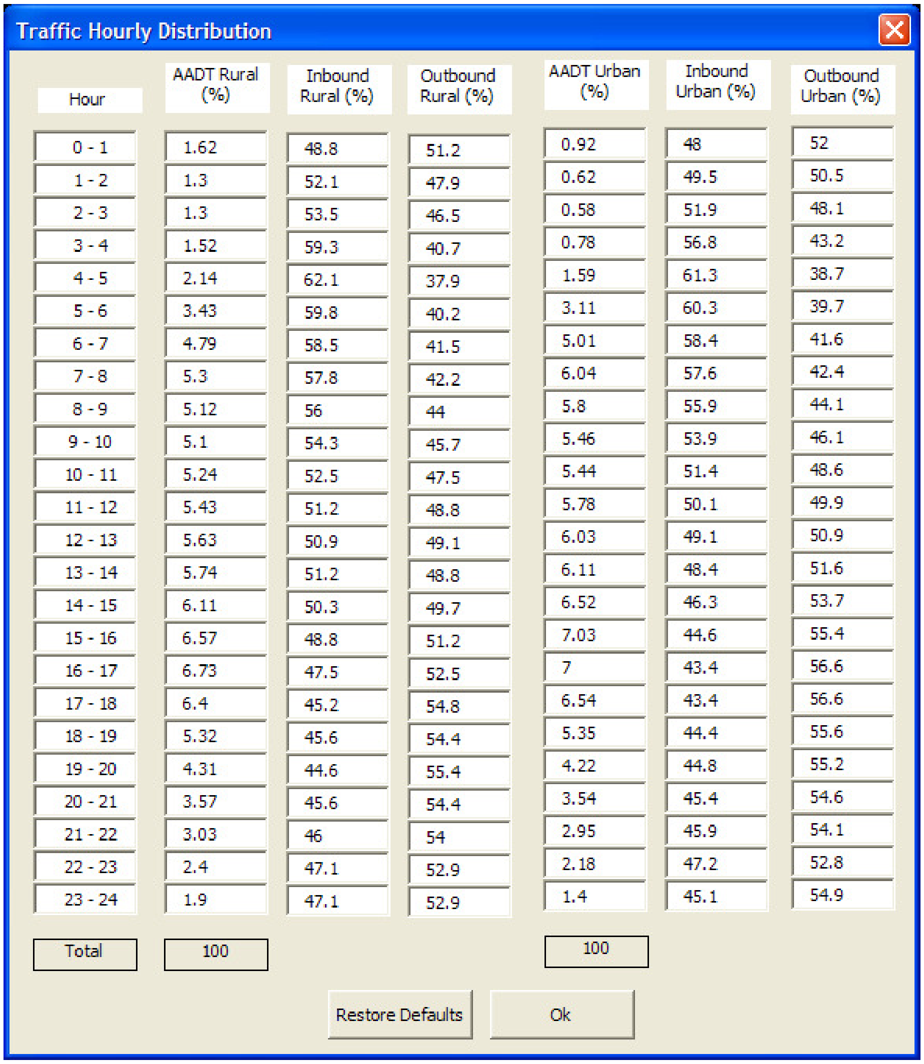


Figure 3-7: Value of User Time Panel

3.3.5 Traffic Hourly Distribution

The "Traffic Hourly Distribution" Panel (Figure 3-8) allows adjustment to (or restoration of) the default values for rural and urban traffic, which are used in converting AADT to an hourly traffic distribution. If project-specific data is not available, use the California weekday (Monday through Friday) default values (Figure 3-8). Select the "Traffic Hourly Distribution" button on the *RealCost* Switchboard (Figure 3-1) to see the default values. These default values were generated from Caltrans traffic count data (April 2005 data by the Division of Traffic Operations) at selected highway locations and can be used for any location in the State.


Traffic Hourly Distribution

Hour	AADT Rural (%)	Inbound Rural (%)	Outbound Rural (%)	AADT Urban (%)	Inbound Urban (%)	Outbound Urban (%)
0 - 1	1.62	48.8	51.2	0.92	48	52
1 - 2	1.3	52.1	47.9	0.62	49.5	50.5
2 - 3	1.3	53.5	46.5	0.58	51.9	48.1
3 - 4	1.52	59.3	40.7	0.78	56.8	43.2
4 - 5	2.14	62.1	37.9	1.59	61.3	38.7
5 - 6	3.43	59.8	40.2	3.11	60.3	39.7
6 - 7	4.79	58.5	41.5	5.01	58.4	41.6
7 - 8	5.3	57.8	42.2	6.04	57.6	42.4
8 - 9	5.12	56	44	5.8	55.9	44.1
9 - 10	5.1	54.3	45.7	5.46	53.9	46.1
10 - 11	5.24	52.5	47.5	5.44	51.4	48.6
11 - 12	5.43	51.2	48.8	5.78	50.1	49.9
12 - 13	5.63	50.9	49.1	6.03	49.1	50.9
13 - 14	5.74	51.2	48.8	6.11	48.4	51.6
14 - 15	6.11	50.3	49.7	6.52	46.3	53.7
15 - 16	6.57	48.8	51.2	7.03	44.6	55.4
16 - 17	6.73	47.5	52.5	7	43.4	56.6
17 - 18	6.4	45.2	54.8	6.54	43.4	56.6
18 - 19	5.32	45.6	54.4	5.35	44.4	55.6
19 - 20	4.31	44.6	55.4	4.22	44.8	55.2
20 - 21	3.57	45.6	54.4	3.54	45.4	54.6
21 - 22	3.03	46	54	2.95	45.9	54.1
22 - 23	2.4	47.1	52.9	2.18	47.2	52.8
23 - 24	1.9	47.1	52.9	1.4	45.1	54.9
Total	100			100		

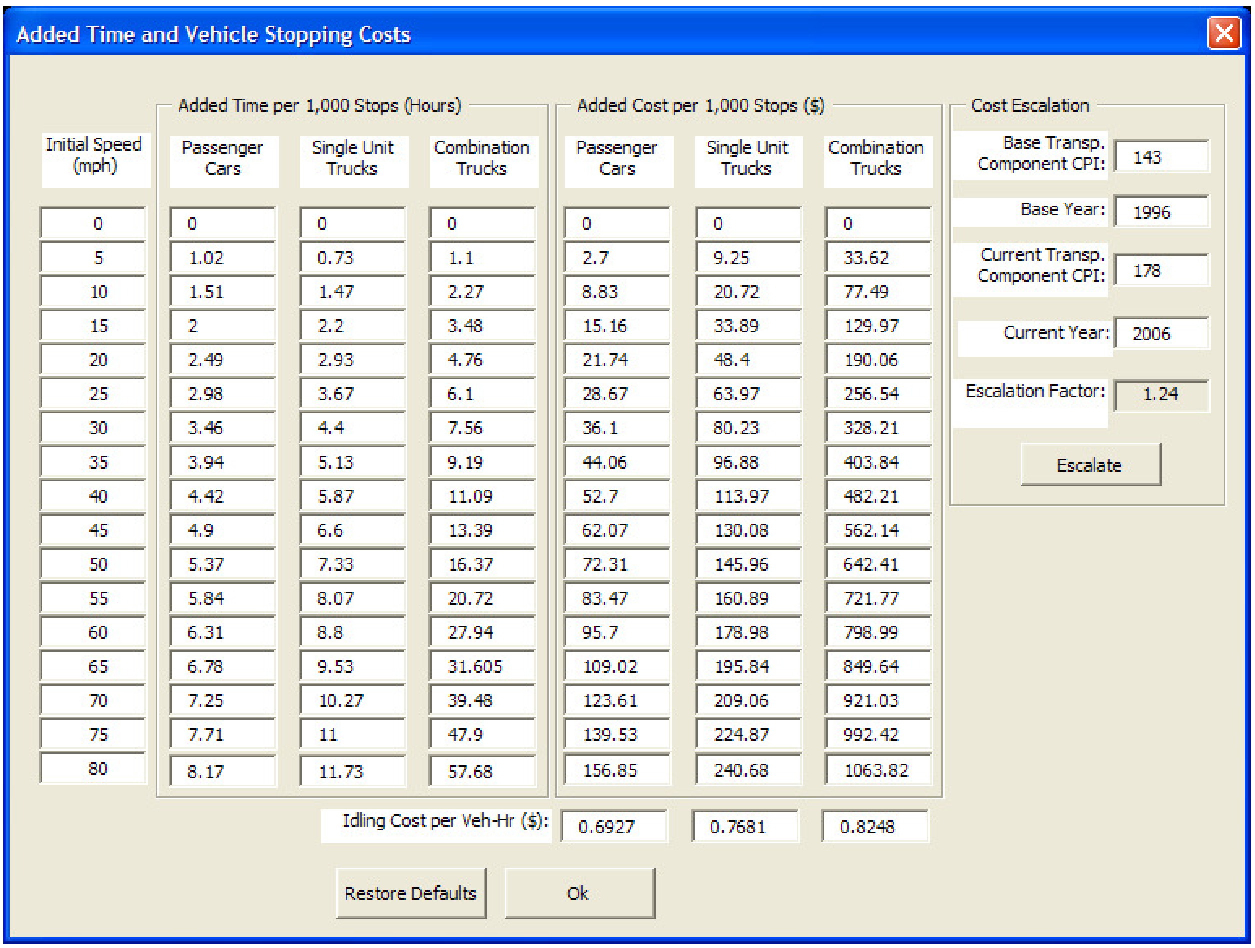
Restore Defaults Ok

Figure 3-8: Traffic Hourly Distribution Panel with California Weekday Default Values

> ***Note:***
> *Currently the program only contains data for weekday "Traffic Hourly Distribution" which will not fit alternatives that use weekend closures. Efforts are currently underway to add a weekend "Traffic Hourly Distribution" to the program. Until the weekend data is included, alternatives that use weekend closures will need to be run separately from the other alternatives and weekend "Traffic Hourly Distribution" data will need to be entered manually. California default weekend "Traffic Hourly Distribution" data can be found in Appendix 7.*

3.3.6 Added Time and Vehicle Stopping Costs

The "Added Time and Vehicle Stopping Costs" panel (Figure 3-9) is used to adjust the default values for added time and added cost per 1,000 stops. The default values are based upon the National Cooperative Highway Research Program (NCHRP) Study 133 (1996), *Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects.* These values are used to calculate user delay and vehicle costs due to speed changes that occur during work zone operations. The "Idling Cost per Veh-Hr ($)" is used to calculate the additional vehicle operating costs that result from moving through a traffic queue under stop-and-go conditions.



Added Time and Vehicle Stopping Costs

Initial Speed (mph)	Added Time per 1,000 Stops (Hours)			Added Cost per 1,000 Stops ($)		
	Passenger Cars	Single Unit Trucks	Combination Trucks	Passenger Cars	Single Unit Trucks	Combination Trucks
0	0	0	0	0	0	0
5	1.02	0.73	1.1	2.7	9.25	33.62
10	1.51	1.47	2.27	8.83	20.72	77.49
15	2	2.2	3.48	15.16	33.89	129.97
20	2.49	2.93	4.76	21.74	48.4	190.06
25	2.98	3.67	6.1	28.67	63.97	256.54
30	3.46	4.4	7.56	36.1	80.23	328.21
35	3.94	5.13	9.19	44.06	96.88	403.84
40	4.42	5.87	11.09	52.7	113.97	482.21
45	4.9	6.6	13.39	62.07	130.08	562.14
50	5.37	7.33	16.37	72.31	145.96	642.41
55	5.84	8.07	20.72	83.47	160.89	721.77
60	6.31	8.8	27.94	95.7	178.98	798.99
65	6.78	9.53	31.605	109.02	195.84	849.64
70	7.25	10.27	39.48	123.61	209.06	921.03
75	7.71	11	47.9	139.53	224.87	992.42
80	8.17	11.73	57.68	156.85	240.68	1063.82
			Idling Cost per Veh-Hr ($):	0.6927	0.7681	0.8248

Cost Escalation

Base Transp. Component CPI:	143
Base Year:	1996
Current Transp. Component CPI:	178
Current Year:	2006
Escalation Factor:	1.24

Escalate

Restore Defaults Ok

Figure 3-9: Added Time and Vehicle Stopping Costs Panel

The default values, expressed in 1996 dollars, are adjusted to the current year dollar amounts by entering the current year and the associated transportation-component Consumer Price Index (CPI). The current year will be the year when construction is expected to begin. Table 7 shows the transportation-component CPI's collected and projected by the California Department of Finance. Since the statewide transportation-component CPI's are not available yet, the U.S. transportation-component CPI's (in bold text) can be used. The values for specific areas like Los Angeles (LA) and San Francisco (SF) can be used for those specific areas.

Example 3.3:

For a 2006 year analysis:

Enter "2006" for "Current Year" and "178.0" for "Current Transp. Component CPI"

***Click the "Escalate" button** (see Figure 3-9).*

The program will update the cost data. To get back to the default values, click the "Restore Defaults" button.

***Note:** 1996 is the default base year.*

Table 7. Transportation Component Consumer Price Indexes*

Year	US	LA CMSA(1)	SF CMSA(2)
1996	**143.0**	144.3	133.5
1997	**144.3**	145.2	133.6
1998	**141.6**	142.6	132.0
1999	**144.4**	146.8	135.8
2000	**153.3**	154.2	143.1
2001	**154.3**	155.3	143.7
2002	**152.9**	154.5	141.0
2003	**157.6**	160.3	145.0
2004	**163.1**	166.5	149.6
2005	**175.2**	176.2	157.3
2006	**178.0**	177.1	159.3
2007	**177.2**	171.6	156.2
2008 & beyond	**177.9**	167.3	154.1

Notes:
* Source: California Department of Finance, Economic Research Unit
http://www.dof.ca.gov/HTML/FS_DATA/LatestEconData/FS_Price.htm
(1) LA CMSA (Consolidated Metropolitan Statistical Area): includes counties of Los Angeles, Orange, Riverside, San Bernadino, & Ventura
(2) SF CMSA (Consolidated Metropolitan Statistical Area): includes counties of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, & Sonoma

3.3.7 Save Project-Level Inputs

To save the project level inputs file, go back to the *RealCost* Switchboard (Figure 3-1) and select the "Save Project-Level Inputs" button, or select "Save LCCA Workbook As…" button to save all modified level inputs including traffic data inputs. *RealCost* will save the project-level inputs at the preferred location specified by the user with the user-specified name. The project input file will be automatically saved with a *.LCC extension. To retrieve the file later, select the "Open Project Level Inputs" button located on the Switchboard.

Note:

Saving the project-level inputs does not make any changes made to default data in "Traffic Hourly Distribution" or "Added Time and Vehicle Stopping Costs." Any of this project-specific data must be reentered when reopening RealCost. If required, use "Save LCCA workbook as" button to save all modified level inputs.

3.3.8 Alternative-Level Inputs

The "Alternative 1" and "Alternative 2" (Figure 3-10) panels are identical and are used to input information for the project alternatives being analyzed Each project alternative can include up to six future rehabilitation activities ("Rehabilitation 1" through "Rehabilitation 6, see Figure 3-10") after the initial construction (i.e., project alternative). The data describing these activities must be entered sequentially according to the pavement M&R schedule associated with each project alternative. For example, "Initial Construction" precedes "Rehabilitation 1" and "Rehabilitation 3" precedes "Rehabilitation 4, etc."

Note:

Because many projects will need at least 3 alternatives analyzed to meet the alternative requirements in Section 2.3 and the program currently can only analyze two alternatives at a time, multiple runs of the program will be needed to cover all the needed alternatives. Caltrans is currently working with FHWA to expand the number of alternatives that can be analyzed at once in the program.

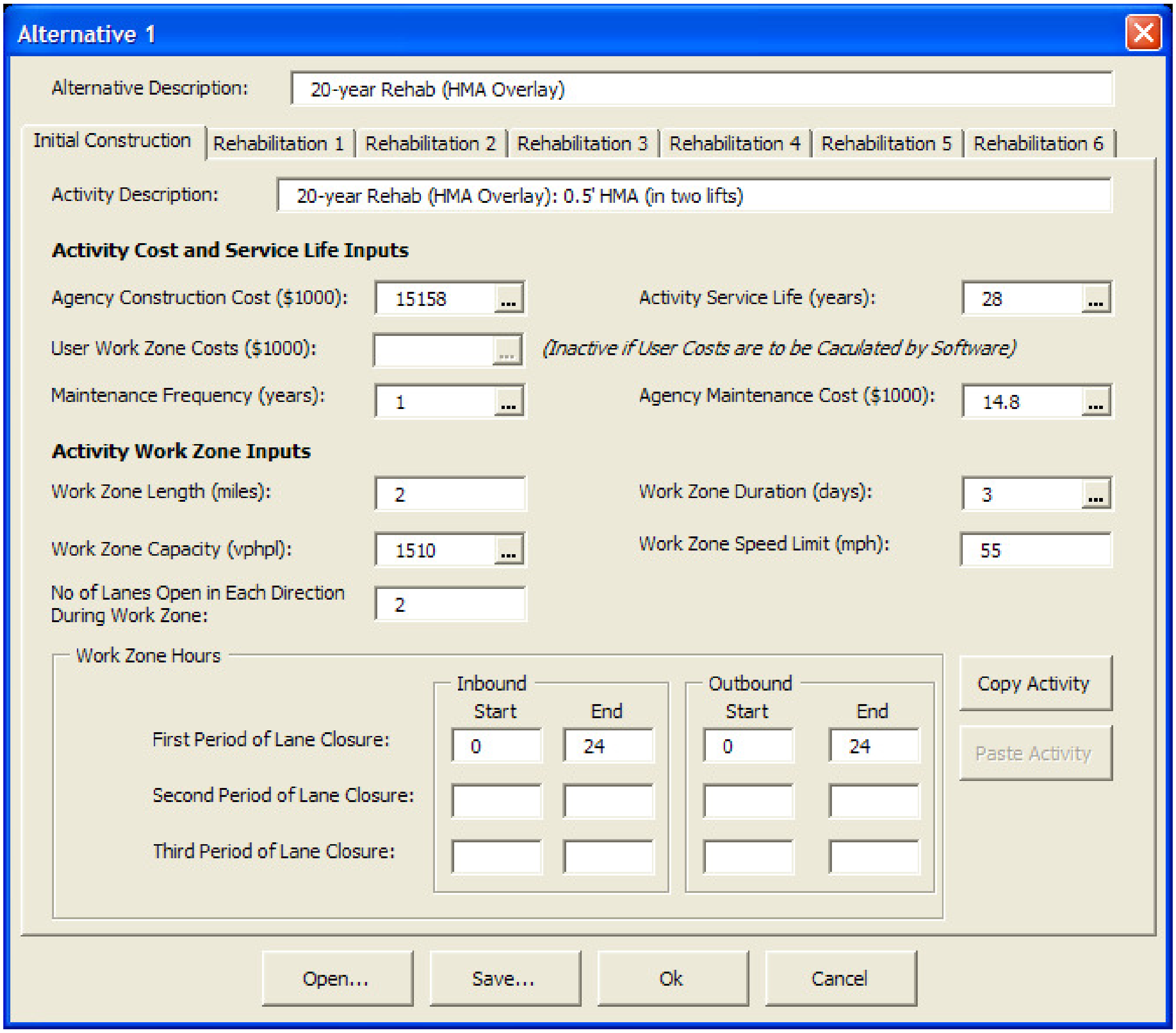


Figure 3-10: Typical Alternative Panel (Alternative 1 shown)

The data inputs required under each activity tab on the panel are described below.

DESCRIPTION

- ***Alternative Description***: Enter a description for the project alternative such as "20-year Rehab (HMA Overlay)."
- ***Activity Description*****:** Enter a description for the initial construction or future rehabilitation activities being considered for each project alternative. For Initial Construction, the activity description will be the same as the alternative description.

ACTIVITY COST AND SERVICE LIFE INPUTS

- ***Agency Construction Cost ($1000):*** Under the "Initial Construction" tab, enter the total initial cost in thousands of dollars (engineer's estimate plus project support costs) for a project alternative (see Section 2.7.1, "Initial Costs"). For future rehabilitation activities after the initial construction (project alternative), enter the total rehabilitation costs (construction cost from table 4 or 5 plus support cost) in thousands of dollars for each future rehabilitation activity (see Section 2.7.3, "Rehabilitation Costs").
- ***Activity Service Life (years):*** Enter the activity service life of initial construction or that of future rehabilitation activities. Refer to Appendix 4 for the appropriate pavement M&R schedule that shows the activity service lives estimated for the initial construction and the future rehabilitation activities to be implemented for each project alternative (see the example in Section 2.7.3, "Rehabilitation Costs").
- ***User Work Zone Costs ($1000):*** This field is inaccessible because the "User Cost Computation Method" in the "Analysis Options" panel (Figure 3-3) is set to "Calculated". If this is not the case, go to "Analysis Options" panel to modify the "User Cost Computation Method."
- ***Maintenance Frequency (years):*** This input refers to the cyclical frequency of interim, preventive, corrective, and routine maintenance treatments to follow after the initial construction or after each future rehabilitation activities. Enter one (1) year as the "Maintenance Frequency," because the cost of the maintenance treatments shown in the M&R schedules have been annualized (see Section 2.7.2).
- ***Agency Maintenance Cost ($1000):*** As discussed in Section 2.7.2, "Maintenance Costs," this includes the costs of preventive, corrective, and routine maintenance treatments to preserve or to extend the service life of initial construction and any future rehabilitation activities. See the example in Section 2.7.3, "Rehabilitation Costs" for details on how to calculate this cost using the appropriate M&R schedule.

ACTIVITY WORK ZONE INPUTS

- ***Work Zone Length (miles):*** This input refers to the length (in miles) of the work zone being considered for initial construction and for each future rehabilitation activity. The work zone length should be based on what is allowed from the Traffic Management Plan (TMP) for the initial construction or historical experience. Note that the Work Zone Length (WZL) is not necessarily the full length of the project limits. It should be measured from beginning to end of the reduced speed area where the work zone speed limit will be in effect daily or nightly. Information and recommendations can be obtained from the District Construction and Traffic Operations if needed. Note that WZL can change from one activity to the next. If uncertain, consult the District Construction Unit or the District Traffic Operations regarding the WZL.
- ***Work Zone Duration (days):*** Refers to the number of days during which the work zone will be affecting traffic. For example, if the work zone is in effect five days a week for four weeks, the duration is twenty. Determine the Work Zone Duration (WZD) using the following formula:

$$WZD = \frac{Lane-miles}{PR} \qquad \text{(Equation 4)}$$

Where **WZD** = Work Zone Duration in days
PR = Productivity Rate in lane-miles per day

Note:

Several special cases to be aware of:

Continuous lane closures – If a lane is closed for the duration of the pavement work, it is treated as a 24-hour closure (from hour 0 to hour 24) for each working day it is closed. Therefore, if the lane is closed for 3 months the total number of closures is 3 months times 21 work days per month, for a total of 63 days.

Weekend (55-hour) closures – multiply 2.3 (=55/24) by the number of closures needed in order to get the number of days needed. This is necessary because the RealCost program can only analyze closures within a 24-hour period and weekend closures last for over 2 days.

Work not requiring a lane closure – In some instances, lanes can be detoured and work can be done behind K-rail or other separation from traffic. In this instance, if lanes do not need to be closed for work done behind the K-rail, the work zone duration (for this work) is zero.

For initial construction, the work zone duration should be estimated as part of establishing the critical path method (CPM) schedule for the project. **Work Zone Duration is not the same as the number of working days used to build the project. WZD is the estimated number of days lane closures are necessary for project construction work.** Use a WZD of zero[1], for each of the competing alternatives, when the initial construction is a new construction or a widening. For future rehabilitations, the estimated work zone must be determined using the total length of pavement structure work (lane-miles) and the corresponding productivity rate from Table 8 or Table 9 (see Equation 4).

Tables 8 and 9 provide the estimates of work that can be completed during different construction windows (nighttime closure, weekend closure, etc.) for typical M&R strategies for flexible pavements (Table 8) and for rigid and composite pavements (Table 9). These production rates are estimates developed using *CA4PRS* (Construction Analysis for Pavement Rehabilitation Strategies) software and assuming typical working conditions and resource configurations observed in past projects.

> ***Note:***
> *The latest version of CA4PRS and the user manual can be obtained from the Division of Research and Innovation Web site at:*
> *http://www.dot.ca.gov/research/roadway/ca4prs/ca4prs.htm.*

Relative to agency costs, user costs can have a major impact on the total life-cycle cost, so it is important to use the most cost effective traffic management practice possible. In some cases, such as when comparing flexible and rigid pavement strategies, the most cost effective traffic management plan may not be the same for all the alternatives (initial and future rehabilitation) being considered. If the traffic management plan does not provide a strategy for the initial or future rehabilitation strategy or if the strategy needs to be checked to be sure it is the most cost effective, the designer can use the construction traffic analysis software CA4PRS (freeways only) to analyze options.

[1] Using a WZD = 0 for the initial construction of each new construction or widening alternative and entering the ultimate lane configuration in “Lanes Open in Each Direction Under Normal Conditions” (“Traffic Data,” Figure 3-5) will generate acceptable results of the analysis of future rehabilitation activities.

- ***Work Zone Capacity (vphpl):*** Enter the vehicular capacity of one lane of the work zone for one hour. Table 6 provides values for typical two-lane and multi-lane highways. As an alternative, the capacity may be estimated using the procedures for "Work Zone Capacity" in Appendix 5.
- ***Work Zone Speed Limit (mph):*** This is the expected operating speed within the work zone. Enter a speed that is 5 mph less than the posted speed limit unless there is an approved reduced speed limit for the project. Approved reductions in posted speed limits can be found in the traffic management plan.
- ***No. of Lanes Open in Each Direction During Work Zone:*** Enter the number of lanes to be open when the work zone is in effect. The number of lanes to be open applies to each direction. This information can be obtained from the traffic management plan or District Traffic Operations.
- ***Work Zone Hours:*** Enter the zone hours using a 24-hour clock (from 0 to 24) during which the work zone is in effect. Work zone timing can be modeled separately for inbound and outbound traffic for up to three separate periods during each day. During these hours, road capacity is limited to the work zone capacity. Work zone hours can be obtained from the TMP or District Traffic Operations. If the traffic management plan includes variable work zone hours (lane closures) for the project, use the hours that apply most often to the project as a whole.

Table 8. Productivity Estimates of Typical Future Rehabilitation Strategies for Flexible Pavements [1,2]

Final Surface Type	Future M&R Alternative	Pavement Design Life (years)	Maintenance Service Level	Average Lane-mile Completed Per Closure[3]				
				Daily Closure (Weekday)		Continuous Closure		Weekend Closure[6] (55-Hour)
				5 to 7-Hour Closure	8 to 12-Hour Closure	16 hour/day Operation[4]	24 hour/day Operation[5]	
CAPM								
HMA	Overlay	5+	1,2,3	0.63	1.50	2.67	4.83	15.13
	Mill & Overlay	5+	1,2,3	0.27	0.64	1.02	1.84	5.16
HMA w/ OGFC	Overlay	5+	1,2,3	0.42	0.92	1.74	3.17	9.92
	Mill & Overlay	5+	1,2,3	0.22	0.41	0.78	1.51	4.41
HMA w/ RHMA	Overlay	5+	1,2,3	0.42	0.92	1.74	3.17	9.92
	Mill & Overlay	5+	1,2,3	0.22	0.41	0.78	1.51	4.41
RHMA-G	Overlay	5+	1,2,3	0.85	1.99	3.55	6.42	20.12
	Mill & Overlay	5+	1,2,3	0.29	0.79	1.24	2.23	6.21
RHMA-G w/ RHMA-O	Overlay	5+	1,2,3	0.32	1.16	2.08	3.79	11.87
	Mill & Overlay	5+	1,2,3	0.24	0.59	0.98	1.77	5.16
Rehabilitation								
HMA	Overlay	10	1,2,3	0.28	0.70	1.41	2.72	8.57
		20	1,2,3	0.18	0.38	1.05	1.91	6.02
	Mill & Overlay	10	1,2,3	0.14	0.37	0.48	1.09	3.26
		20	1,2,3	0.06	0.26	0.25	0.75	2.19
HMA w/ OGFC	Overlay	10	1,2,3	0.23	0.44	1.03	2.08	6.58
		20	1,2,3	0.16	0.50	0.63	1.53	4.96
	Mill & Overlay	10	1,2,3	0.13	0.33	0.40	0.94	2.91
		20	1,2,3	0.06	0.24	0.40	0.60	2.03
HMA w/ RHMA	Overlay	10	1,2,3	0.23	0.44	1.03	2.08	6.58
		20	1,2,3	0.16	0.50	0.63	1.53	4.96
	Mill & Overlay	10	1,2,3	0.13	0.33	0.40	0.94	2.91
		20	1,2,3	0.06	0.24	0.40	0.60	2.03
RHMA-G	Overlay	10	1,2,3	0.63	1.50	2.67	4.83	15.13
		20	1,2,3	0.42	0.92	1.74	3.17	9.92
	Mill & Overlay	10	1,2,3	0.27	0.64	1.02	1.84	5.16
		20	1,2,3	0.18	0.31	0.65	1.30	3.77
RHMA-G w/ RHMA-O	Overlay	10	1,2,3	0.42	0.92	1.74	3.17	9.92
		20	1,2,3	0.32	0.64	1.26	2.34	7.39
	Mill & Overlay	10	1,2,3	0.22	0.41	0.78	1.51	4.41
		20	1,2,3	0.16	0.37	0.54	1.12	3.32

Notes:
UD - Under Development. See Office of Pavement Design for Assistance
(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.
(2) Refer to Appendix 3 for a expanded version of the table.
(3) Production rates in this table are based on representative assumptions that are applied consistently throughout the table.
These rates are only for calculating future user costs for the procedures in this manual and not for any other purpose.
More project specific user costs for some freeway situations can be obtained from the CA4PRS software.
(4) 24-hour continuous closure with 16 hours of operation per day
(5) 24-hour continuous closure with 24 hours of operation per day
(6) 55-hour extended closure over the weekend

Table 9. Productivity Estimates of Typical Future Rehabilitation for Rigid and Composite Pavements (1,2)

Final Surface Type	Future M&R Alternative		Pavement Design Life (years)	Maintenance Service Level	Average Lane-mile Completed Per Closure[3]				
					Daily Closure (Weekday)		Continuous Closure		Weekend Closure[6] (55-Hour)
					5 to 7-Hour Closure	10-Hour Closure	16 hour/day Operation[4]	24 hour/day Operation[5]	
CAPM									
Flexible / Composite	Flexible Overlay		5+	1,2,3	0.85	1.99	3.55	6.42	20.12
	Flexible Overlay w/ Slab Replacements **(FO + JPCP SR)**	4-hr RSC	5+	1,2,3	0.31	1.55	2.91		
		12-hr RSC					1.47	4.45	16.19
Rigid - Jointed Plain Concrete Pavement (JPCP)	Concrete Pavement Rehab A[3]	4-hr RSC	5+	1,2,3	0.14	2.00	4.57		
		12-hr RSC					0.71	4.14	23.71
	Concrete Pavement Rehab B[4]	4-hr RSC	5+	1,2,3	0.20	2.80	6.40		
		12-hr RSC					1.00	5.80	33.20
	Concrete Pavement Rehab C[5]	4-hr RSC	5+	1,2,3	0.50	7.00	16.00		
		12-hr RSC					2.50	14.50	83.00
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	Punchout Repairs A[7]	4-hr RSC	5+	1,2,3	0.37	2.12	1.48		
		12-hr RSC					1.11	4.72	24.01
	Punchout Repairs B[8]	4-hr RSC	5+	1,2,3	0.13	0.84	1.60		
		12-hr RSC					0.68	2.32	8.88
	Punchout Repairs C[9]	4-hr RSC	5+	1,2,3	0.50	7.00	16.00		
		12-hr RSC					2.50	14.50	83.00
Rehabilitation									
Flexible / Composite	Flexible Overlay w/ Slab Replacement **(FO + JPCP SR)**	4-hr RSC	10	1,2,3	0.13	0.84	1.60		
	Flexible Overlay w/ Slab Replacement **(FO + JPCP SR)**	12-hr RSC					0.68	2.32	8.88
	Mill, Slab Replacement & Overlay **(MSRO)**	4-hr RSC	10	1,2,3	0.27	2.12	4.48		
	Mill, Slab Replacement & Overlay **(MSRO)**	12-hr RSC					1.11	4.72	24.01
	Mill, Slab Replacement & Overlay **(MSRO)**	4-hr RSC	20		0.19	2.01	4.25		
	Mill, Slab Replacement & Overlay **(MSRO)**	12-hr RSC					0.88	4.38	22.94
	Crack, Seat, & Flexible Overlay **(CSFOL)**		10	1,2,3	0.28	0.70	1.41	2.72	8.57
			20		0.23	0.44	1.03	2.08	6.58
	Replace with Flexible		20	1,2,3	0.10	0.40	0.67	1.23	3.95
			40		0.06	0.30	0.51	0.83	2.81
	Replace with Composite	4-hr RSC	20	1,2,3	0.01	0.04	0.18		
		12-hr RSC					0.10	0.13	0.60
		4-hr RSC	40	1,2,3	0.01	0.03	0.15		
		12-hr RSC					0.10	0.11	0.50
Rigid - Jointed Plain Concrete Pavement (JPCP)	Lane Replacement	4-hr RSC	20	1,2,3	0.02	0.09	0.18		
		12-hr RSC					0.12	0.16	0.70
		4-hr RSC	40	1,2,3	0.02	0.05	0.16		
		12-hr RSC					0.10	0.15	0.60
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	Lane Replacement	4-hr RSC	20	1,2,3	0.01	0.03	0.13		
		12-hr RSC					0.08	0.11	0.50
		4-hr RSC	40	1,2,3	0.01	0.02	0.12		
		12-hr RSC					0.06	0.10	0.40

FO= Flexible Overlay JPCP = Jointed Plain Concrete Pavement SR = Slab Replacement RSC = Rapid Set Concrete
CRCP = Continuously Reinforced Concrete Pavement

Notes:
UD - Under Development. See Office of Pavement Design for Assistance
(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.
(2) Refer to Appendix 3 for a expanded version of the table.
(3) Production rates are based on the lower end of the representative assumptions for the range and are applied consistently throughout the table. These rates are only for calculating future user costs for the procedures in this manual and not for any other purpose. More project specific user costs for some freeway situations can be obtained from the CA4PRS software.
(4) 24-hour continuous closure with 16 hours of operation per day
(5) 24-hour continuous closure with 24 hours of operation per day
(6) 55-hour extended closure over the weekend
(7) Punchout Repair A involves **significant** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced concrete pavements that had previous punchout repairs and a flexible overlay.
(8) Punchout Repair B involves **moderate** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced concrete pavements where the total number of current and previous punchout repairs exceed 4 per mile.
(9) Punchout Repair C involves **minor** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced concrete pavements that where the total number of current and previous punchout repairs do not exceed 4 per mile.

Note:

For weekend closures, enter 0 to 24 on first period line.

Example 3.4:

Determine the "Activity Work Zone Inputs" for future rehabilitation activities of the following project alternative:

CAPM (HMA Overlay)

- *20.4 lane-miles (project length 3.4 miles, 3 lanes in each direction, mainline only) of existing flexible pavement*
- *Work Zone Duration (days): 12 days based upon the following information from the traffic management plan or assumed:*
  - *(a) Typical lane closure from 8 PM till 6 AM the next morning.*
  - *(b) Single-lane paving with two lanes closed at one time.*
  - *(c) Approximately 1.7 lane-miles will be overlaid during each closure*
  - *(d) Work Zone Length of 1.4 miles for each closure*
- *Initial Construction Year: same as the beginning year of the analysis period*
- *Climate Region: South Coast*
- *Analysis Period: 20 years.*
- *Maintenance Service Level 2*

Solution

1) *Find the applicable pavement M&R schedule for the project alternative being considered. (from Appendix 4, Table F-1 (a))*

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5		10		15	
CAPM												
HMA	5+	1,2	Year of Action		0		5				15	
			Activity Description		**CAPM HMA**		Rehab HMA (10 yr)				CAPM HMA	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile)	5	1,100	10	6,100			5	1,100
		3	Year of Action		0				10			
			Activity Description		**CAPM HMA**				CAPM HMA			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile)	10	6,200			10	6,100		

2) *Identify the future rehabilitation activities (including CAPM and reconstruction) whose year of action falls before the end of analysis period (20 years for this example.)*

   (a) *10-year Rehab in Year 5*

   (b) *5-year CAPM in Year 15*

3) *Find the applicable M&R alternative for each future rehabilitation activity ("Future M&R Alternative" in Table 8 or 9). From Table 8 for the:*

   (a) *10-year Rehab in Year 5: HMA Overlay or Mill and Overlay;*

   (b) *CAPM in Year 15: HMA Overlay or Mill and Overlay*

4) *Find the applicable production rate estimate for each future rehabilitation activity (from Table 8)*

   (a) *10-year Rehab in Year 5*

   - *10-year HMA Overlay (8-12 hours): 0.70 lane-miles/closure*
   - *10-year HMA Mill and Overlay (8-12 hours): 0.37 lane-miles/closure*

   (b) *5-year CAPM in Year 15: all the work zone inputs are assumed to be same as for initial construction*

   - *CAPM (HMA Overlay): 1.50 lane-miles/closure*
   - *CAPM (HMA, Mill and Overlay): 0.64 lane-miles/closure*

5) *While the TMP calls for an 8 PM to 6 AM nighttime closure for the initial construction (CAPM Overlay), the closure window could, and often does, change for future rehabilitation activities.*

6) *Check with Traffic Operations or Construction for an appropriate closure window to use with each of the future rehabilitation activities or follow the procedure described in Section 3.3.8. For simplicity in this example, the same closure window will be used in all the future rehab activities as in the initial construction.*

7) *Divide the total number of paving lane-miles by the production rate of the preferred construction window to get the "Work Zone Duration" (in terms of number of closures required):*

   (a) *10-year Rehab in Year 5*

   - *Overlay 20.4/0.70 = 29.1 ≈ 30*
   - *Mill and Overlay 20.4/0.37 = 55.1 ≈ 56.*

   (b) *5-year CAPM in Year 15:*

   - *Overlay = Same as the above 10-year Rehab in Year 5.*
   - *Mill and Overlay 20.4/0.64 = 31.88 ≈ 32*

Inputs to RealCost

1) *CAPM in Year 0: (to be entered under "Initial Construction" tab of the "Alternative 1" panel in RealCost--see Figure 3-10)*

   (a) *Work Zone Length (miles): 2*
   (b) *Work Zone Duration (days): 12*
   (c) *Work Zone Capacity (vphpl): 1,510 (from Table 6)*
   (d) *Work Zone Speed Limit (mph): 60*
   (e) *No of Lanes Open in Each Direction: 1 (two out of the three lanes closed for single-lane paving)*
   (f) *Work Zone Hours: Will use 2 periods:*
      - *First period 0 –6*
      - *Second Period 20 –24*

2) *10-year Rehab in Year 5: (to be entered under "Rehabilitation 1" tab of the "Alternative 1" panel in RealCost--see Figure 3-10)*

	Overlay	**Mill and Overlay**
Work Zone Length (miles)	2	2
Work Zone Duration (days)	30	56
Work Zone Capacity (vphpl from table 6)	1510	1510
Work Zone Speed Limit (mph)	60	60
No of Lanes Open in Each Direction	1	1
Work Zone Hours	0 – 6 20 - 24	0 – 6 20 - 24

3) *CAPM in Year 15: [to be entered under "Initial Construction" tab of "Alternative 1" panel in RealCost (Figure 3-10)]*

	Overlay (same as initial)	**Mill and Overlay**
Work Zone Length (miles)	2	2
Work Zone Duration (days)	12	32
Work Zone Capacity (vphpl from table 6)	1510	1510
Work Zone Speed Limit (mph)	60	60
No of Lanes Open in Each Direction	1	1
Work Zone Hours	0 – 6 20 - 24	0 – 6 20 - 24

To save the alternative-level inputs file, click the “Save” button at the bottom of the “Alternative” panel (see Figure 3-10). *RealCost* will save the alternative-level inputs in the location and /with the name specified by the user. The project alternative-input file will be automatically saved with a *.LCA extension. To load the file when re-entering *RealCost*, click the “Open” button located at the bottom of the “Alternative” panel.

Note:

Be sure to provide the minimum information in all six “Rehabilitation” tabs to avoid an error message. The minimum inputs are: Activity Service Life, Work Zone Length, Work Zone Capacity, Work Zone Speed Limit, and No. of Lanes Open in Each Direction During Work Zone. Zero can be entered in the remaining input fields.

3.4 Input Warnings and Errors

To see a list of missing or potentially erroneous data, click the “Show Warnings” button in the “Switchboard” (Figure 3-1) before running the analysis. Note: “Warnings” call attention to certain inputs that fall out of expected ranges and do not necessarily indicate input errors. “Errors” are fatal inputs that will prevent the program from running and providing LCCA results. If “Warnings” or “Errors” occur, it is advisable to recheck inputs and project assumptions to ensure the analysis is realistic and accurate.

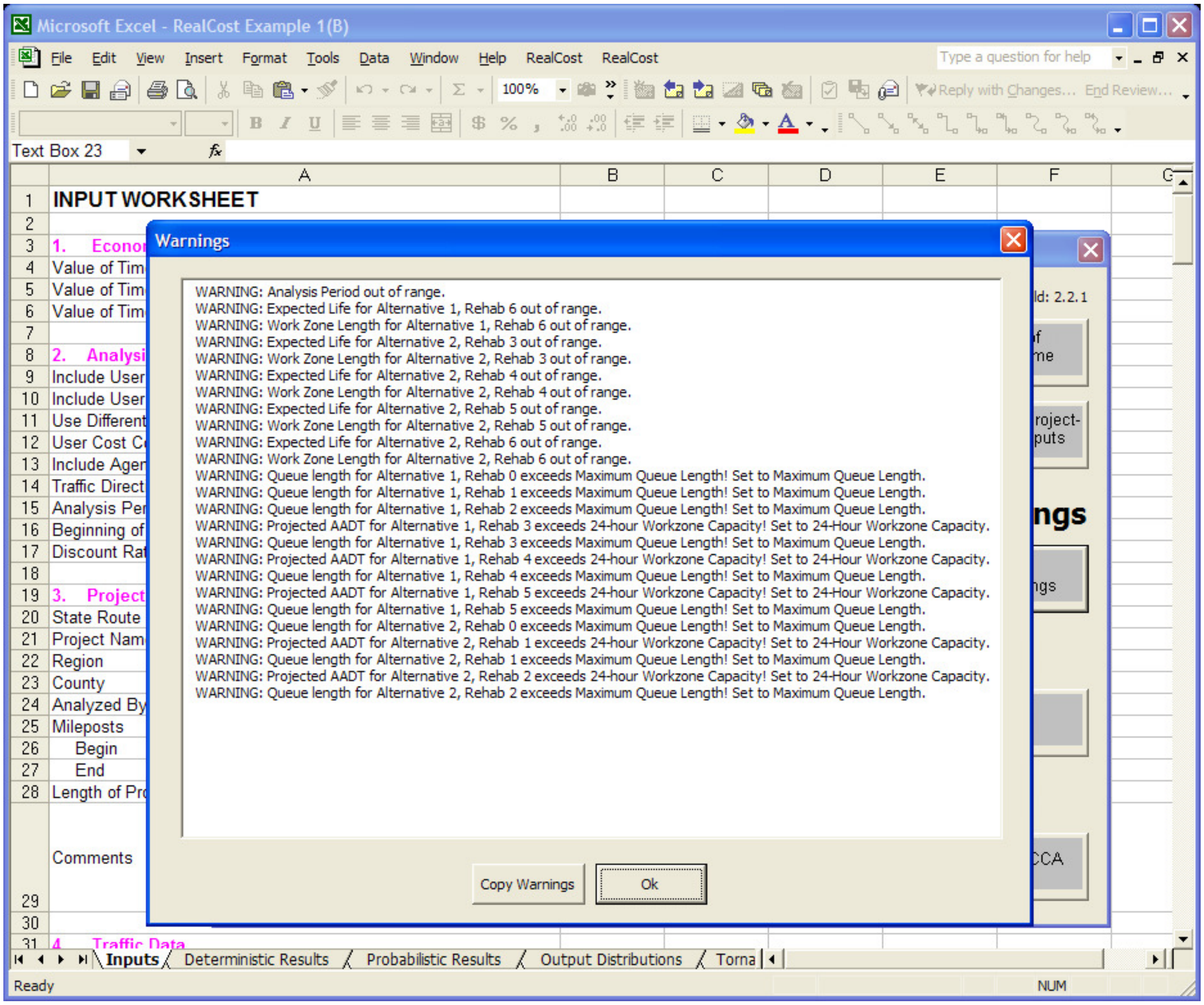


Figure 3-11: Input Warnings

3.5 Simulation and Outputs

The "Simulation and Outputs" section of the *RealCost* Switchboard (Figure 3-1) includes buttons to view deterministic life-cycle cost results and buttons to run simulations of probabilistic inputs.

- *Deterministic Results*: Click this button to have *RealCost* calculate and display deterministic values for both agency and user costs based upon the deterministic inputs. The "Deterministic Results" panel (Figure 3-12) provides a direct link ("Go to Worksheet" button) to the "Deterministic Results Excel Worksheet" that contains all the information needed to investigate the deterministic results.

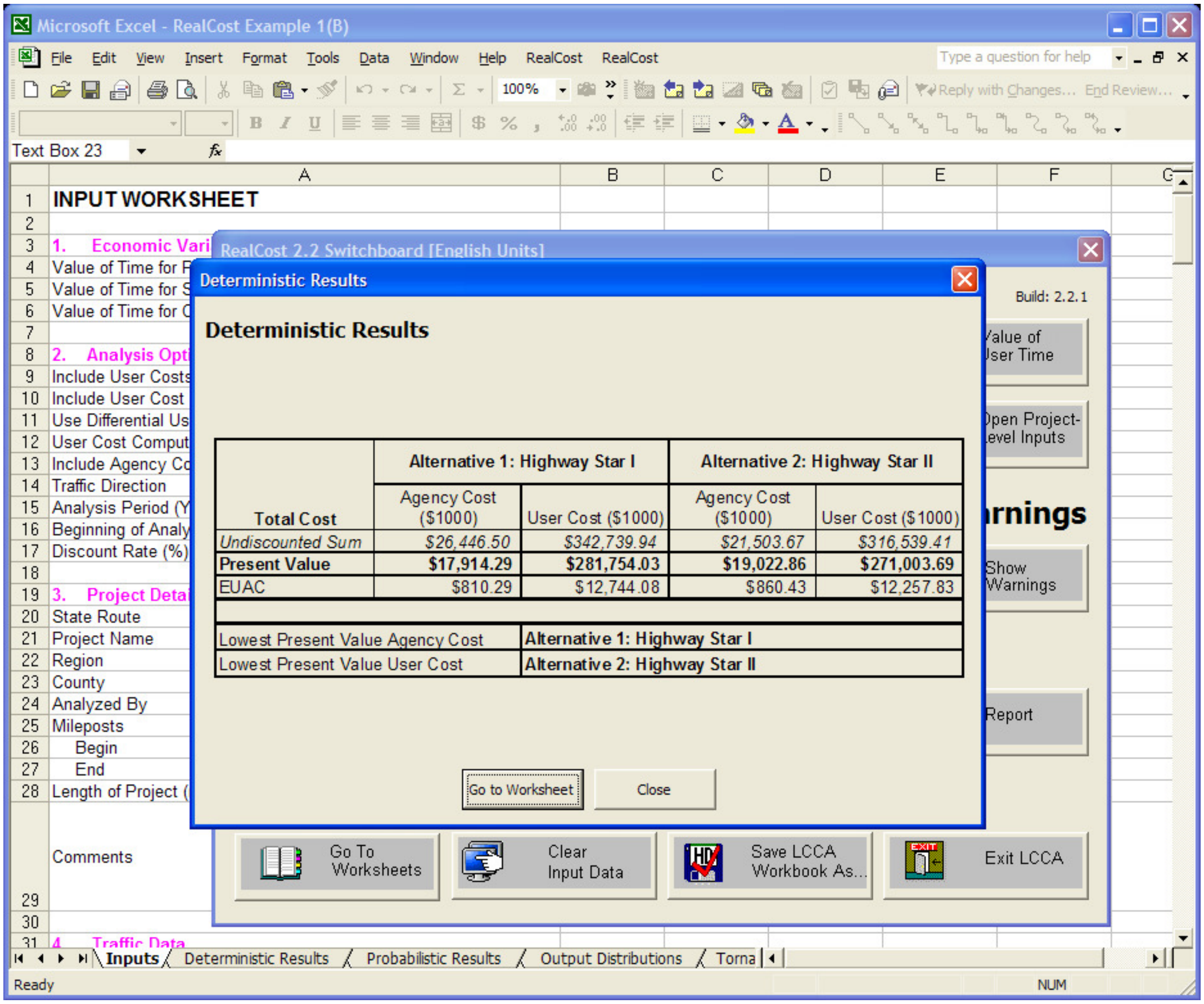


Figure 3-12: Deterministic Results Panel

- *Simulation*: Clicking this button will initiate Monte Carlo simulation of probabilistic inputs. At present it is not being used.
- *Probabilistic Results*: Clicking this button will display probabilistic results. At present it is not being used.
- *Reports*: Click this button to have *RealCost* produce a twelve-page report (Figure 3-13) that shows inputs and results. The last two pages include results of the probabilistic analysis, which will be blank if no probabilistic inputs are entered.

RealCost Report

1/12

RealCost 2.2 Report **8/24/2006**

RealCost Input Data

1. Economic Variables	
Value of Time for Passenger Cars ($/hour)	$ 11.51
Value of Time for Single Unit Trucks ($/hour)	$ 27.83
Value of Time for Combination Trucks ($/hour)	$ 27.83

2. Analysis Options	
Include User Costs in Analysis	Yes
Include User Cost Remaining Service Life Value	Yes
Use Differential User Costs	Yes
User Cost Computation Method	Calculated
Include Agency Cost Remaining Service Life Value	Yes
Traffic Direction	Inbound
Analysis Period (Years)	55
Beginning of Analysis Period	2005
Discount Rate (%)	4.0

3. Project Details and Quantity Calculations	
State Route	Highway Star
Project Name	Smoke on the Water
Region	Montreaux
County	Deep Purple
Analyzed By	Gov't Mule
Mileposts	
Begin	0.00
End	5.00
Length of Project (miles)	5.00
Comments	We all came out to Montreaux......Smoke on the water. Fire in the sky......

4. Traffic Data	
AADT Construction Year (total for both directions)	200,000
Cars as Percentage of AADT (%)	90.0
Single Unit Trucks as Percentage of AADT (%)	3.0
Combination Trucks as Percentage of AADT (%)	7.0
Annual Growth Rate of Traffic (%)	2.5
Speed Limit Under Normal Operating Conditions (mph)	65
No of Lanes in Each Direction During Normal Conditions	4
Free Flow Capacity (vphpl)	2074
Rural or Urban Hourly Traffic Distribution	Urban
Queue Dissipation Capacity (vphpl)	1818
Maximum AADT (total for both directions)	400,000
Maximum Queue Length (miles)	10.0

Save As... Close

Figure 3-13: *RealCost* Report

3.6 Administrative Functions

The "Administrative Functions" section of the *RealCost* Switchboard (Figure 3-1) allows the user to save, clear, retrieve data, and close the "Switchboard" or *RealCost*.

- *Go to Worksheets*: Clicking this button will allow direct access to any input or result worksheet.
- *Clear Input Data*: Clicking this button clears the project-level inputs, alternative-level inputs, and results from the program and the worksheets.
- *Save LCCA Workbook As...*: Clicking this button allows you to save the entire Excel workbook, including all inputs and results worksheets, under a user-specified name.
- *Exit LCCA*: Clicking this button will close *RealCost*.

CHAPTER 4 – ANALYZING LCCA RESULTS

4.1 Purpose of LCCA

Life-cycle cost analysis is a project evaluation tool that compares the economic impacts of different alternatives. The data and procedures in this manual are not designed to provide cost-benefit (non-economic) or network level analysis. The goal of this LCCA Procedures Manual is to provide consistent analysis by making the same assumptions between equivalent alternatives in order to determine the most cost effective strategy.

The results (dollar values) from LCCA performed using *RealCost* and this manual should not be used for project budgeting or estimating. Although life-cycle costs are reported in dollars, the results should be viewed as a relative comparison of cost effectiveness between the alternatives analyzed. The costs generated by *RealCost* are not an estimate of the actual cost to the Department or the public Life-cycle cost analysis is not a means to predict the future. By using the same methodology (established by this manual) to analyze alternative pavement strategies over a given analysis period, most differences between assumptions inherent in the analysis and future developments are negated by the comparison between alternatives.

To generate reasonable and consistent results, the alternatives being evaluated through LCCA must provide equivalent benefits, although the costs and scheduled activities between alternatives will typically vary in amount and timing over the analysis period. For example, alternatives that only differ in design life or pavement surface type are considered to have equivalent benefits. Conversely, an alternative that includes widening or increases vehicle capacity is not equivalent to a strategy that only rehabilitates an existing pavement structure. Similarly, a preventative maintenance strategy such as a slurry or chip seal is not equivalent to a pavement rehabilitation overlay that adds design strength to the pavement structure.

4.2 Status of the LCCA Procedures Manual

This manual includes a variety of tables and data developed for Department users to run the *RealCost* program, which was developed by the Federal Highway Administration (FHWA). The data found in this manual is based on the most accurate information available at this time from Department historical data, computer modeling, FHWA, the California Department of Finance, and other sources. Data and modeling improvements will be made from time to time to improve the user-friendliness of LCCA process and the accuracy of the results. In particular, cost data will need to be changed periodically due to market fluctuation, inflation, and policy changes. Future updates of this manual will strive to capture the most accurate information available.

4.3 *RealCost*

Just as LCCA is a tool for project alternative evaluation, *RealCost* is a tool for LCCA. As with any tool, *RealCost* has limits. It is a software program designed to model actual project conditions in order to compare the costs of selected alternatives over a given analysis period (the life-cycle).

Users should be mindful of the “garbage in, garbage out” mentality. How well *RealCost* models a project is determined by the complexity of the conditions and the engineering judgment of the user. To assure the consistency of the analysis and to minimize the amount of time needed to perform an analysis, data tables for costs, schedules, and user cost inputs have been generated using existing Department data and other sources. In some cases (such as the Future Maintenance and Rehabilitation Schedules in Appendix 4), the data in the tables is the only data to be used for the analysis. In other cases, the data tables are provided as defaults in case more detailed project specific data is not available (such as in Table 6 or Figure 3-8).

Although data tables and instructions are intended to cover nearly all the situations that may be encountered with a project, situations will arise that are not covered in the manual. Because LCCA involves nearly every aspect of a project, it is advisable to seek out experience within an office, district, or region to take advantage of institutional knowledge within the Department and verify any assumptions made as part of the analysis. As with any engineering analysis or estimate, LCCA calculations should be checked and verified to ensure quality results. At a minimum, the results should be analyzed for input errors, excessive cost differences between alternatives, and given a reality check (do the inputs and outputs make sense?). The more time and care is invested in developing accurate input data, the better the quality of the results. However, investing more time refining inputs is not always justified since the models in *RealCost* may not be sensitive enough to certain variables to change the ultimate conclusion of the LCCA. Users can try varying inputs and analyzing the results to see if a finer analysis is warranted.

4.3.1 Project Conditions and *RealCost*

Despite the numerous inputs in the *RealCost* program, the geometric and traffic models are relatively simple compared to typical project conditions. For projects with multiple segments, routes, or project types (new construction and rehabilitation together), the user should break the project down and run *RealCost* separately for each component to get the most accurate results. For variable closure windows (number of lanes, day of the week, month, traffic direction), and variable geometrics (number of lanes available), the user may want to break the project down into multiple segments or scenarios and run *RealCost* separately for each component to see how the results change. Given the variable sensitivity of the software model to different inputs, an alternative solution is to vary the inputs and analyze the results to determine if more in-depth analysis is necessary. How a project is broken down is subject to the engineering judgment of the user. Potential methods include adjusting the post mile inputs in *RealCost* or using a percentage of the total cost based on relative project lengths or surface area. For variable Traffic Management Plan (TMP) requirements, a reasonable assumption may be to use the requirements that cover the majority of the project while considering whether they are over- or underestimating user costs.

4.4 Agency and User Costs

LCCA is focused around quantifying two distinct types of costs throughout the project limits over a given analysis period: agency costs and user costs. Agency costs are estimated using engineering quantities and historical costs of previous projects (initial project estimate), Table 4 (for existing flexible surfaces) or Table 5 (for existing rigid surfaces), as well as the M&R Schedules in Appendix 4 of this manual. There are multiple cost inputs aimed at estimating the direct cost to the Department.

User costs are an estimate of the costs associated with delaying the traveling public during initial project construction and subsequent maintenance and rehabilitation activities within the analysis period. They are based on predicted traffic volumes, stage construction, traffic handling, user delay cost rates, and additional vehicle operating costs. User delay cost is calculated by multiplying the additional travel time resulting from roadwork by the assigned user delay cost rate. The additional vehicle operating costs are determined by multiplying the additional vehicle cost (from speed changes, stops, and idle time) by the assigned dollar value. User costs are related to project activities but are an indirect cost (not directly borne by the Department).

4.4.1 Limitations of LCCA Results

Agency Costs:

- In early phases of project development, detailed information is limited, so project estimates for initial construction costs may not be accurate. The most important need at this stage is to be sure that the estimates and assumptions used for each alternative are equivalent and consistent.

- The Maintenance and Rehabilitation (M&R) Schedules in Appendix 4 are a model for planning and scheduling pavement activities. They represent a typical scenario for maintaining a particular type of pavement based on previously generated Maintenance decision trees and generally accepted statewide and national practice. The M&R Schedules assume funds will be available to apply the treatments when needed and should not be viewed as what has actually been done historically or a guarantee of what will occur in the future.

- General inflation is not accounted for in LCCA because it is assumed that inflation will be the same for all alternatives. This is considered to be a reasonable approach since the analysis is focused on relative comparison between alternatives. However, future increases in certain material and labor costs or changes in project requirements may cause some products or strategies to inflate at a different rate over time. Since it is not possible to predict how much differential change (if any) may occur, inflation is not accounted for in the analysis.

User Costs:

- User costs are sensitive to the assigned user delay cost rate (value of user time) and vehicle operating costs (added time and vehicle stopping costs) since they are the only cost components of the estimate. To be consistent in comparing alternatives, Caltrans uses values from Division of Traffic Operations Memorandum to District Deputy Directors dated March 3rd, 2006 and NCHRP Study 133 (1996).
- User costs are heavily dependent on assumed staging and traffic handling plans (number of lanes open, closure hours, productivity, number of closures, and especially maximum queue length), components that are mostly controlled by the contractor and typically vary throughout project construction.
- The geometric and traffic models in *RealCost* are relatively simple compared to typical conditions on most projects, which can greatly affect the prediction of user costs. By applying the same assumptions to all alternatives, the analysis should provide a reasonable comparison between alternatives. A more accurate assessment of user costs can be made for some projects by using the CA4PRS software program, which is available on the Division of Research and Innovation (DRI) website at http://www.dot.ca.gov/research/roadway/ca4prs/index.htm.
- Variations in future growth, user driving habits, and alternate routes available during construction can affect the accuracy of user cost estimates.

4.4.2 Comparing Agency & User Costs

The Department currently considers agency and user costs equivalent, but when analyzing LCCA results it is advisable to compare the individual agency and user costs for each alternative being considered in addition to the total costs. For projects proposed on highway corridors with large traffic volumes, user costs can have significantly greater impact than agency costs. User costs for each alternative should be compared to determine if there is a disproportionately high or low impact on users. If an alternative has the lowest agency cost but excessively high user costs, the traffic management assumptions should be re-examined or an alternative that has somewhat higher agency costs but much lower user costs may be preferable.

4.4.3 Choosing an Alternative

Other than the mandatory design standards detailed in Topic 612, "Pavement Design Life," of the Highway Design Manual, there is no requirement to choose the alternative with the lowest total life-cycle cost. Some possible reasons to choose another alternative other than the one with the lowest life-cycle cost include safety, scope, schedule, constructability, environmental, additional benefits (such as historical material performance), accommodation of future growth or capacity improvements, or political reasons. Any LCCA project decisions should be justified and documented in the PID, PR, or other appropriate project document (see PDPM Appendix O-O).

4.5 Projects with Different Pavement Design Lives

When a project has two different pavement design lives within the same project (such as a widening to last 20 years and an overlay of existing pavement that will last only 5 years), the initial costs will need to be divided into two (or more) projects representing the costs to do each component with different pavement design lives and analyzed separately using life-cycle cost analysis. The results of the separate life-cycle cost analysis will then need to be combined to produce the overall project result.

REFERENCES

1. Federal Highway Administration, “Life-Cycle Cost Analysis in Pavement Design,” FHWA-SA-98-079, Pavement Division Interim Technical Bulletin, September 1998.

2. Federal Highway Administration, Life-Cycle Cost Analysis, *RealCost* User Manual, August 2004.

3. Federal Highway Administration, “Life-Cycle Cost Analysis Primer,” August 2002.

4. California Department of Transportation, “2004 State of the Pavement,” Division of Maintenance, Office of Roadway Rehabilitation and Roadway Maintenance, July 2005.

5. California Department of Transportation, “Highway Design Manual,” Sixth Edition, September 2006.

6. California Department of Transportation, “Historical Cost Analysis of Capital Outlay Support for FYs 1998 to 2002,” Division of Project Management, Office of Project Workload and Data Management, May 2005.

7. Washington State Department of Transportation, “Pavement Type Selection Protocol,” Environmental and Engineering Program Division, January 2005.

APPENDIX 1: GLOSSARY AND LIST OF ACRONYMS

A. Glossary

Analysis Period: the period of time during which the initial and any future costs for the project alternatives will be evaluated.

Activity Service Life: the estimated time period that the asset will remain viable for public use (at or above a minimum level of service).

CApital Preventive Maintenance (CAPM): CAPM consists of work performed to preserve the existing pavement structure utilizing strategies that preserve or extend pavement service life. See HDM Index 603.2 and the CAPM Guidelines (DIB 81) for further information.

Composite Pavement: pavements comprised of both rigid and flexible layers. Currently, for purposes of the procedures in the HDM, only flexible over rigid composite pavements are considered composite pavements.

Continuously Reinforced Concrete Pavement (CRCP): one type of rigid pavement with reinforcing steel and no transverse joints except at construction joints or paving stops for more than 30 minutes. CRCP pavements are reinforced in the longitudinal direction, and additional steel is also used in the transverse direction to hold the longitudinal steel. Due to the continuous reinforcement in the longitudinal direction, the pavement develops transverse cracks spaced at close intervals. These cracks develop due to changes in the concrete volume, restrained by the longitudinal reinforcement steel, resulting from moisture and temperature variation. Crack width can affect the rate of corrosion of the reinforcing steel at the crack locations when water or de-icing salts (if used) penetrate the cracks. In a well-designed CRCP, the longitudinal steel should be able to keep the transverse cracks tightly closed.

Crack, Seat, and Flexible Overlay (CSFOL): A rehabilitation strategy for rigid pavements. CSFOL practice requires the contractor to crack and seat the rigid pavement slabs, and place a flexible overlay with a pavement reinforcing fabric (PRF) interlayer.

Flexible Pavement: Pavements engineered to transmit and distribute traffic loads to the underlying layers. The highest quality layer is the surface course (generally asphalt binder mixes), which may or may not incorporate underlying layers of a base and a subbase. These types of pavements are called “flexible” because the total pavement structure bends or flexes to accommodate deflection bending under traffic loads.

Hot Mix Asphalt (HMA): formerly known as asphalt concrete (AC), is a graded asphalt concrete mixture (aggregate and asphalt binder) containing a small percentage of voids which is used primarily as a surface course to provide the structural strength needed to distribute loads to underlying layers of the pavement structure.

Hot Mix Asphalt with Open Graded Friction Course (HMA w/ OGFC): Open graded friction course (OGFC), formerly known as open graded asphalt concrete (OGAC), is a wearing course placed on top of HMA. OGFC is a wearing course mix consisting of asphalt binder and aggregate with relatively uniform grading and little or no fine aggregate and mineral filler. OGFC is designed to have a large number of void spaces in the compacted mix as compared to hot mix asphalt.

Hot Mix Asphalt with Rubberized Hot Mix Asphalt (HMA w/ RHMA): Rubberized hot mix asphalt (RHMA), formerly known as rubberized asphalt concrete (RAC), is a wearing course placed on top of HMA. RHMA is a material produced for hot mix applications by mixing either asphalt rubber or asphalt rubber binder with graded aggregate. RHMA may be gap- (RHMA-G) or open- (RHMA-O) graded.

Jointed Plain Concrete Pavement (JPCP): one type of rigid pavement, also referred to as Portland Cement Concrete Pavement (PCCP), constructed with longitudinal and transverse joints. JPCPs do not contain steel reinforcement, other than tie bars and dowel bars. JPCPs are doweled in the transverse joints to improve load transfer and prevent faulting of the slabs from occurring. Tie bars are used in the longitudinal joints to hold adjoining slabs together.

Lane Replacement: the removal of individual slabs (or panels) of concrete pavement where the total length of consecutive slabs is greater than 100 feet.

Maintenance Service Level (MSL): Caltrans uses a three class system, termed 'Maintenance Service Level' (MSL), to distinguish the role of various highways within the state highway network.

- MSL 1 – Contains route segments in urban areas functionally classified as Interstate, Other Freeway/Expressway, or Other Principal Arterial. In rural areas, the MSL 1 designation contains route segments functionally classified as Interstate or Other Principal Arterial
- MSL 2 – Contains route segments classified as Other Freeway/Expressway, or Other Principal Arterial not in MSL 1, and route segments functionally classified as minor arterials not in MSL 3
- MSL 3 – Indicates a route or route segment with the lowest maintenance priority. Typically, MSL 3 contains route segments functionally classified as major or minor collectors and local roads, route segments with relatively low traffic volumes. Route segments where route continuity is needed are also assigned MSL 3 designation.

The MSL can be found in the Pavement Condition Report developed by the Division of Maintenance.

Pavement Structure: The planned, engineered system of layers of specified materials (typically consisting of surface course, base, and subbase) placed over the subgrade soil to support the cumulative traffic loading anticipated during the design life of the pavement. The pavement is also referred to as the pavement structure and has been referred to as pavement structural section.

Open Graded Friction Course (OGFC): Formerly known as open graded asphalt concrete (OGAC), OGFC is a wearing course mix consisting of asphalt binder and aggregate with relatively uniform grading and little or no fine aggregate and mineral filler. OGFC is designed to have a large number of void spaces in the compacted mix as compared to hot mix asphalt.

Pavement Design Life: Also referred to as performance period, is the period of time that a newly constructed or rehabilitated pavement is engineered to perform before reaching a condition that requires at least CApital Preventive Maintenance (CAPM) or before reaching its terminal serviceability. The selected pavement design life varies depending on the characteristics of the highway facility, the objective of the project, and projected traffic volume and loading. See HDM Topic 612 for more information.

<u>Rapid Strength Concrete (RSC):</u> Also known as Rapid Set Concrete, which is a type of concrete that cures in 3 to 24 hours. RSC is used to replace concrete slabs and lanes during short construction windows where conventional Portland cement concrete will not have time to cure and gain strength.

<u>Rehabilitation:</u> Rehabilitation is work undertaken to extend the service life of an existing facility. This includes placement of an overlay and/or other work necessary to return an existing roadway, including shoulders, to a condition of structural or functional adequacy, for the specified service life. This might include the partial or complete removal and replacement of portions of the pavement structure. Rehabilitation work is classified as pavement rehabilitation activities and roadway rehabilitation activities

<u>Remaining Service Life Value (RSV):</u> The value of the remaining activity service life beyond the end of the analysis period of a project alternative.

<u>Rigid Pavement:</u> pavements with a rigid surface course (typically Portland cement concrete or a variety of specialty cement mixes for rapid strength concretes), which may incorporate underlying layers of stabilized or non-stabilized base or subbase materials. These types of pavements rely on the substantially higher stiffness rigid slab to distribute the traffic loads over a relatively wide area of underlying layers and the subgrade. Some rigid slabs have reinforcing steel to help resist cracking due to temperature changes and repeated loading.

<u>Rubberized Hot Mix Asphalt (RHMA):</u> a material produced for hot mix applications by mixing either asphalt rubber or rubberized asphalt binder with graded aggregate. RHMA may be gap- (RHMA-G), or open- (RHMA-O) graded.

<u>Rubberized Hot Mix Asphalt-Gap Graded (RHMA-G):</u> a gap graded mixture of crushed coarse and fine aggregate, and of paving asphalt that are combined with specified percentages of granulated (crumb) reclaimed rubber. RHMA-G can be used as either a surface course or a non-structural wearing course.

<u>Rubberized Hot Mix Asphalt-Open Graded (RHMA-O):</u> same as RHMA-G, except RHMA-O is used only as a non-structural wearing course.

Slab Replacement: the removal of individual slabs (or panels) of concrete pavement with the total length of consecutive slabs being 100 feet or less.

Terminal Serviceability: the condition of the pavement at the end of its pavement design life. In California, this is defined as a condition that requires a CAPM, a major rehabilitation or reconstruction.

B. List of Acronyms

AADT	=	Annual Average Daily Traffic
BCA	=	Benefit-Cost Analysis
Caltrans	=	California Department of Transportation
Cal-B/C	=	California Life-Cycle Benefit/Cost Model
CAPM	=	CApital Preventive Maintenance
CRCP	=	Continuously Reinforced Concrete Pavement
CSFOL	=	Crack, Seat, and Flexible Overlay
FHWA	=	Federal Highway Administration
FO	=	Flexible Overlay
HDM	=	Highway Design Manual
HMA	=	Hot Mix Asphalt
JPCP	=	Jointed Plain Concrete Pavement
LCCA	=	Life-Cycle Cost Analysis
M&R	=	Maintenance & Rehabilitation/Reconstruction
MSL	=	Maintenance Service Level
MSRO	=	Mill, Slab Replacement & Overlay
OGFC	=	Open Graded Friction Course
PA&ED	=	Project Approval & Environmental Document
pcphpl	=	passenger cars per hour per lane
PDPM	=	Project Development Procedures Manual
PID	=	Project Initiation Document
PR	=	Project Report
PSSR	=	Project Scope Summary Report

RHMA	=	Rubberized Hot Mix Asphalt
RHMA-G	=	Rubberized Hot Mix Asphalt-Gap Graded
RHMA-O	=	Rubberized Hot Mix Asphalt-Open Graded
RSC	=	Rapid Strength Concrete
RSL	=	Remaining Service Life
SR	=	Slab Replacement
TI	=	Traffic Index
vph	=	vehicles per hour
vphpl	=	vehicles per hour per lane

APPENDIX 2: LIST OF *REALCOST* LIMITATIONS AND BUGS

A. Notes:

RealCost appears to calculate salvage value based on a round-down if activity service life is a decimal of less than 0.5 year. Don't use decimals in the activity service life.

When all the rehabilitation tabs are not used, copy the last rehabilitation tab in the remaining empty rehabilitation tabs. *RealCost* will not use all tabs within an alternative; it will only use in the calculation the tabs up through the end of the analysis period.

When saving the project-level inputs file, *RealCost* will not save the escalation in the "Added Time and Vehicle Stopping Costs" panel (Figure 3-9). Escalate these values every time *RealCost* is re-started.

B. Limitations to the Program:

RealCost only allows for six subsequent maintenance/rehabilitation activities in the life-cycle of an alternative. Note, the maintenance and rehabilitation schedules do not list more than six maintenance/rehabilitation subsequent activities.

RealCost can only analyze two alternatives at once. To analyze multiple alternatives, run the program enough times to analyze each alternative and manually compare the results.

APPENDIX 3: PRODUCTIVITY ESTIMATES OF TYPICAL M&R STRATEGIES

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APPENDIX 4: TYPICAL PAVEMENT M&R SCHEDULES FOR CALIFORNIA

The following pavement M&R schedules are the consolidation of the "Pavement M&R Decision Trees" (used for activity scheduling) included in Caltrans districts' ten-year pavement plans. Currently, each Caltrans district has its own set of pavement decision trees, most of which have different sequences of pavement M&R activities, depending on route class (alternatively known as maintenance service level) and pavement type. The following compilation of California-specific pavement M&R schedules has been developed to simplify the selection of a pavement M&R schedule for the LCCA.

The categorization of these California-specific pavement M&R schedules was based on four factors: the climate region, maintenance service level, existing pavement type/final surface type, and project type/initial M&R strategy (i.e., project alternative). The nine climate regions shown in Figure A4-1 are grouped into the five climate regions (i.e., All Coastal, Inland Valley, High Mountain & High Desert, Desert, and Low Mountain & South Mountain; see Table 14), and the pavement M&R decisions applicable to these five climate regions are collected from the district offices.

If a pavement decision tree for a particular pavement type was not available for a particular climate region, a similar decision tree from another region was utilized. For pavement decision trees for products with limited to no examples available in California (such as continuously reinforced concrete pavement), information from national sources and other states with similar climates/products was used.

Remaining Service Life (RSL)

When doing a widening project with a RSL alternative that is different from the values in the M&R Schedules, the life of the initial activity must be adjusted to reflect the difference in pavement design life. So for example, if a widening project has a RSL alternative of 25 years, and the service life of the initial activity in the M&R schedule for a 20-year pavement design life is 23 years, then the initial activity period that should be entered into *RealCost* should be 28 years (23 + 5 from difference in remaining life of existing pavement to theoretical 20-year pavement.)

Table 14. Caltrans Climate Region Classification

Caltrans Climate Regions	**Climate Regions for Pavement M&R Schedules**
North Coast	All Coastal
Central Coast	
South Coast	
Inland Valley	Inland Valley
High Mountain	High Mountain and High Desert
High Desert	
Desert	Desert
Low Mountain	Low Mountain and South Mountain
South Mountain	

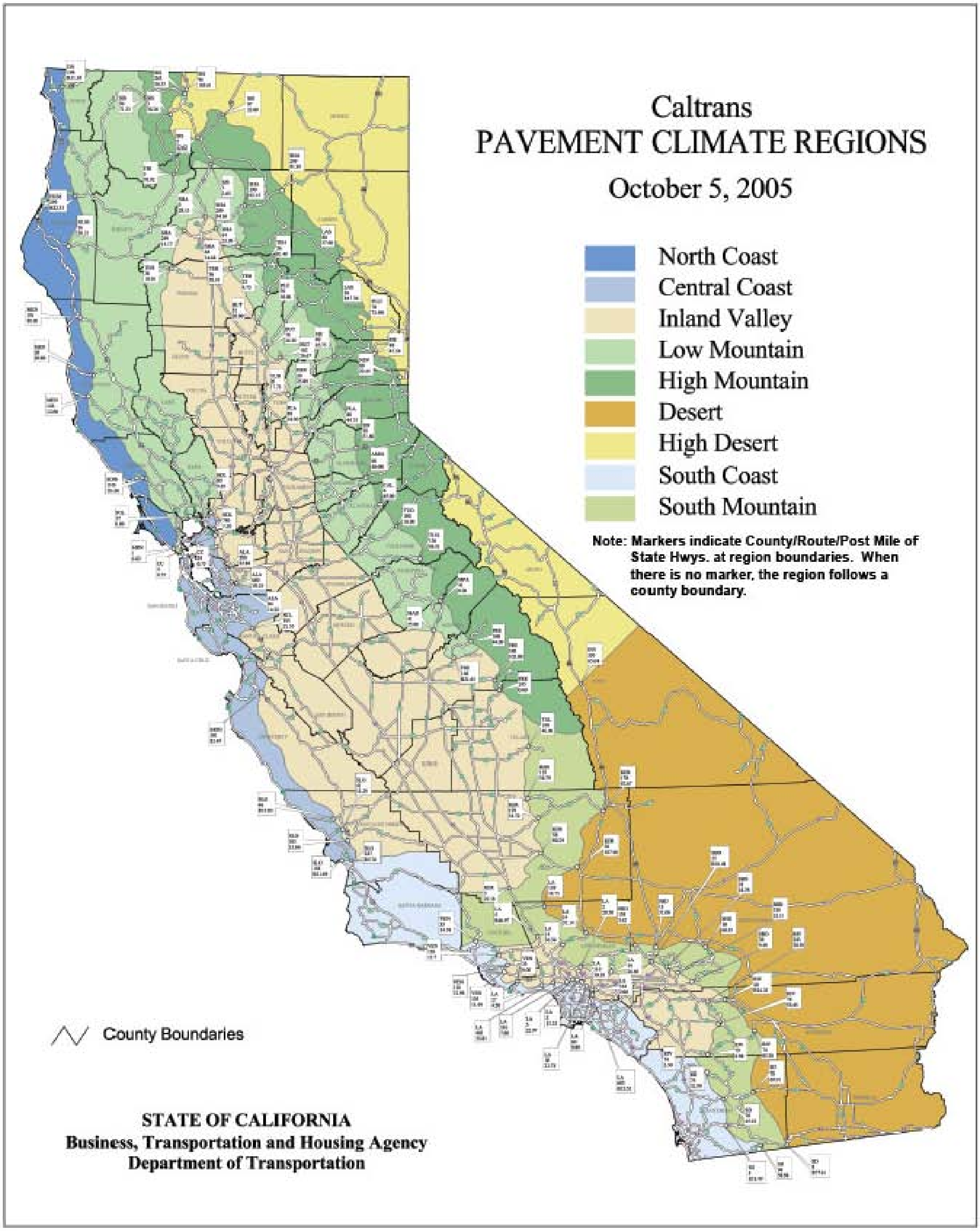

Figure A4-1: Map of Caltrans Climate Regions

(This map can be found at http://www.dot.ca.gov/hq/esc/Translab/ope/Climate.html)

TABLE F-1 (a)
All Coastal Climate Regions
HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA	20	1,2	Year of Action	0				20	25				45	50	
			Activity Description	**New / Reconstruct**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years)	20				5	20				5	20	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,300				1,100	2,900				1,100	2,900	
		3	Year of Action	0				20		30		40	45		
			Activity Description	**New / Reconstruct**				CAPM HMA		CAPM HMA		CAPM HMA	Lane Replace (20 yr)		
			Activity Service Life (years)	20				10		10		5	20		
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,300				6,100		6,100		1,100	3,300		
CAPM															
HMA	5+	1,2	Year of Action	0	5										
			Activity Description	**CAPM HMA**	Rehab HMA (20 yr)										
			Activity Service Life (years)	5	20										
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,100	2,900										
		3	Year of Action	0		10									
			Activity Description	**CAPM HMA**		CAPM HMA									
			Activity Service Life (years)	10		10									
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	6,200		6,100									
Rehabilitation															
HMA	20	1,2,3	Year of Action	0				20	25				45	50	
			Activity Description	**Rehab HMA (20 yr)**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years)	20				5	20				5	20	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,900				1,100	2,900				1,100	2,900	
			Year of Action	0											
			Activity Description	**HMA New/Reconst**	Select a HMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-1 (b)
All Coastal Climate Regions
HOT MIX ASPHALT W/ OGFC PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5		10		15		20		25		30		35		40		45		50		55	
New Construction/Reconstruction																												
HMA w/ OGFC	20	1,2	Year of Action		0										22				32								54	
			Activity Description		**New / Reconstruct**										CAPM HMA w/ OGFC				Rehab HMA w/ OGFC (20 yr)								CAPM HMA w/ OGFC	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,300									10	3,700			22	3,600							10	3,700
		3	Year of Action		0										22				32				42				52	
			Activity Description		**New / Reconstruct**										CAPM HMA w/ OGFC				CAPM HMA w/ OGFC				CAPM HMA w/ OGFC				Lane Replace (20 yr)	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,300									10	3,700			10	6,800			10	6,800			22	2,300
	40	1,2	Year of Action		0																40				50			
			Activity Description		**New / Reconstruct**																CAPM HMA w/ OGFC				Rehab HMA w/ OGFC (20-yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	5,200															10	3,700			22	2,300		
		3	Year of Action		0																40				50			
			Activity Description		**New / Reconstruct**																CAPM HMA w/ OGFC				CAPM HMA w/ OGFC			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	5,200															10	3,700			10	3,700		
CAPM																												
HMA w/ OGFC	5+	1,2	Year of Action		0				10																			
			Activity Description		**CAPM HMA w/ OGFC**				Rehab HMA w/ OGFC (20 yr)																			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,700			22	2,300																		
		3	Year of Action		0				10																			
			Activity Description		**CAPM HMA w/ OGFC**				CAPM HMA w/ OGFC																			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,700			10	6,800																		
Rehabilitation																												
HMA w/ OGFC	20	1,2,3	Year of Action		0										22				32								54	
			Activity Description		**Rehab HMA w/ OGFC (20 yr)**										CAPM HMA w/ OGFC				Rehab HMA w/ OGFC (20 yr)								CAPM HMA w/ OGFC	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,300									10	4,000			22	3,200							10	4,000
			Year of Action		0																							
			Activity Description		**New / Reconstruct**		Select a HMA w/ OGFC schedule for New Construction/Reconstruction from this M&R table																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life																								
	40	1,2,3	Year of Action		0																40				50			
			Activity Description		**Rehab HMA w/ OGFC (40 yr)**																CAPM HMA w/ OGFC				Lane Replace (40 yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	5,700															10	3,700			40	5,700		
			Year of Action		0																							
			Activity Description		**New / Reconstruct**		Select a HMA w/ OGFC schedule for New Construction/Reconstruction from this M&R table																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life																								

TABLE F-1 (c)
All Coastal Climate Regions
HOT MIX ASPHALT W/ RHMA PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA w/ RHMA	20	1,2	Year of Action	0					23		33				
			Activity Description	**New / Reconstruct**					CAPM HMA w/ RHMA		Rehab HMA w/ RHMA (20 yr)				
			Activity Service Life (years)	23					10		23				
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,700					3,500		3,500				
		3	Year of Action	0					23		33		43		53
			Activity Description	**New / Reconstruct**					CAPM HMA w/ RHMA		CAPM HMA w/ RHMA		CAPM HMA w/ RHMA		Lane Replace (20 yr)
			Activity Service Life (years)	23					10		10		10		23
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,700					3,500		6,500		6,500		2,700
	40	1,2	Year of Action	0								40		50	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ RHMA		Rehab HMA w/ RHMA (20 yr)	
			Activity Service Life (years)	40								10		23	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	4,000								3,500		2,700	
		3	Year of Action	0								40		50	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ RHMA		CAPM HMA w/ RHMA	
			Activity Service Life (years)	40								10		10	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	4,000								3,500		3,500	
CAPM															
HMA w/ RHMA	5+	1,2	Year of Action	0		10									
			Activity Description	**CAPM HMA w/ RHMA**		Rehab HMA w/ RHMA (20 yr)									
			Activity Service Life (years)	10		23									
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,500		3,500									
		3	Year of Action	0		10									
			Activity Description	**CAPM HMA w/ RHMA**		CAPM HMA w/ RHMA									
			Activity Service Life (years)	10		10									
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,500		7,600									
Rehabilitation															
HMA w/ RHMA	20	1,2,3	Year of Action	0					23		33				
			Activity Description	**Rehab HMA w/ RHMA (20 yr)**					CAPM HMA w/ RHMA		Rehab HMA w/ RHMA (20 yr)				
			Activity Service Life (years)	23					10		23				
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,500					3,500		3,500				
			Year of Action	0											
			Activity Description	**New / Reconstruct**						Select a HMA w/ RHMA schedule for New Construction/Reconstruction from this M&R table					
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	40	1,2,3	Year of Action	0								40		50	
			Activity Description	**Rehab HMA w/ RHMA (40 yr)**								CAPM HMA w/ RHMA		Lane Replace (40 yr)	
			Activity Service Life (years)	40								10		40	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	4,800								3,500		4,000	
			Year of Action	0											
			Activity Description	**New / Reconstruct**						Select a HMA w/ RHMA schedule for New Construction/Reconstruction from this M&R table					
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-1 (d)
All Coastal Climate Regions
RUBBERIZED HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
RHMA	20	1,2	Year of Action	0					22	28				50	
			Activity Description	**New / Reconstruct**					CAPM RHMA	Rehab RHMA (20 yr)				CAPM RHMA	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	22 2,200					6 900	22 2,500				6 900	
		3	Year of Action	0					22		32		42		51
			Activity Description	**New / Reconstruct**					CAPM RHMA		CAPM RHMA		CAPM RHMA		Lane Replace (20 yr)
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	22 2,200					10 4,100		10 4,000		9 4,400		22 2,200
CAPM															
RHMA	5+	1,2	Year of Action	0		6									
			Activity Description	**CAPM RHMA**		Rehab RHMA (20 yr)									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	6 900		22 2,500									
		3	Year of Action	0		10									
			Activity Description	**CAPM RHMA**		CAPM RHMA									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 4,000		10 4,100									
Rehabilitation															
RHMA	20	1,2,3	Year of Action	0				22		28				50	
			Activity Description	**Rehab RHMA (20 yr)**				CAPM RHMA		Rehab RHMA (20 yr)				CAPM RHMA	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	22 2,500				6 900		22 2,900				6 900	
			Year of Action	0	Select a RHMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-1 (e)
All Coastal Climate Regions
RUBBERIZED HOT MIX ASPHALT W/ RHMA-O PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	35	40	45	50	55
New Construction/Reconstruction														
RHMA w/ RHMA-O	20	1,2	Year of Action	0					24	35				
			Activity Description	**New / Reconstruct**					CAPM RHMA w/ RHMA-O	Rehab RHMA w/ RHMA-O (20 yr)				
			Activity Service Life (years)	24					11	24				
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,700					3,100	1,900				
		3	Year of Action	0					24	35			46	
			Activity Description	**New / Reconstruct**					CAPM RHMA w/ RHMA-O	CAPM RHMA w/ RHMA-O			CAPM RHMA w/ RHMA-O	
			Activity Service Life (years)	24					11	11			11	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,700					3,100	7,000			7,000	
	40	1,2	Year of Action	0							40			51
			Activity Description	**New / Reconstruct**							CAPM RHMA w/ RHMA-O			Rehab RHMA w/ RHMA-O
			Activity Service Life (years)	40							11			24
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,800							3,100			1,900
		3	Year of Action	0							40			51
			Activity Description	**New / Reconstruct**							CAPM RHMA w/ RHMA-O			CAPM RHMA w/ RHMA-O
			Activity Service Life (years)	40							11			11
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,800							3,100			7,000
CAPM														
RHMA w/ RHMA-O	5+	1,2	Year of Action	0			11							
			Activity Description	**CAPM RHMA w/ RHMA-O**			Rehab RHMA w/ RHMA-O (20 yr)							
			Activity Service Life (years)	11			24							
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,800			1,900							
		3	Year of Action	0			11							
			Activity Description	**CAPM RHMA w/ RHMA-O**			CAPM RHMA w/ RHMA-O							
			Activity Service Life (years)	11			11							
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,800			7,000							
Rehabilitation														
RHMA w/ RHMA-O	20	1,2,3	Year of Action	0					24	35				
			Activity Description	**Rehab RHMA w/ RHMA-O (20 yr)**					CAPM RHMA w/ RHMA-O	Rehab RHMA w/ RHMA-O (20 yr)				
			Activity Service Life (years)	24					11	24				
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,900					3,300	1,900				
			Year of Action	0	Select a RHMA w/ RHMA-O schedule for New Construction/Reconstruction from this M&R table									
			Activity Description	**New / Reconstruct**										
			Activity Service Life (years)											
			Annual Maint. Cost ($/lane-mile) over Activity Service Life											
	40	1,2,3	Year of Action	0							40			51
			Activity Description	**Rehab RHMA w/ RHMA-O (40 yr)**							CAPM RHMA w/ RHMA-O			Lane Replace (40 yr)
			Activity Service Life (years)	40							11			40
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	5,000							3,300			3,800
			Year of Action	0	Select a RHMA w/ RHMA-O schedule for New Construction/Reconstruction from this M&R table									
			Activity Description	**New / Reconstruct**										
			Activity Service Life (years)											
			Annual Maint. Cost ($/lane-mile) over Activity Service Life											

TABLE F-2 (a)
Inland Valley Climate Region
HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA	20	1,2	Year of Action	0				18	23				41	46	
			Activity Description	**New / Reconstruct**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	18 3,600				5 1,100	18 2,700				5 1,100	18 2,700	
		3	Year of Action	0				18		27		36	43		
			Activity Description	**New / Reconstruct**				CAPM HMA		CAPM HMA		CAPM HMA	Lane Replace (20 yr)		
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	18 3,600				9 5,600		9 4900		7 5,700	18 3,600		
CAPM															
HMA	5+	1,2	Year of Action	0	5										
			Activity Description	**CAPM HMA**	Rehab HMA (20 yr)										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 1,100	18 2,700										
		3	Year of Action	0		9		18							
			Activity Description	**CAPM HMA**		CAPM HMA		CAPM HMA							
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	9 5,600		9 5,100		7 5,700							
Rehabilitation															
HMA	20	1,2,3	Year of Action	0				18	23				41	46	
			Activity Description	**Rehab HMA (20 yr)**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	18 2,700				5 1,100	18 2,700				5 1,100	18 2,700	
			Year of Action	0											
			Activity Description	**New / Reconstruct**	Select a HMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-2 (b)
Inland Valley Climate Region
HOT MIX ASPHALT W/ OGFC PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Cells in the Activity Service Life rows give: Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life.

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA w/ OGFC	20	1,2	Year of Action	0				20		28				48	
			Activity Description	**New / Reconstruct**				CAPM HMA w/ OGFC		Rehab HMA w/ OGFC (20 yr)				CAPM HMA w/ OGFC	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 2,700				8 / 4,400		20 / 3,600				8 / 4,400	
		3	Year of Action	0				20		30		40		50	
			Activity Description	**New / Reconstruct**				CAPM HMA w/ OGFC		CAPM HMA w/ OGFC		CAPM HMA w/ OGFC		Lane Replace (20 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 2,700				10 / 3,700		10 / 6,800		10 / 6,800		20 / 2,700	
	40	1,2	Year of Action	0								38		48	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ OGFC		Rehab HMA w/ OGFC (20-yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	38 / 6,400								10 / 3,400		20 / 3,600	
		3	Year of Action	0								38		48	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ OGFC		CAPM HMA w/ OGFC	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	38 / 6,400								10 / 3,400		10 / 3,400	
CAPM															
HMA w/ OGFC	5+	1,2	Year of Action	0		8									
			Activity Description	**CAPM HMA w/ OGFC**		Rehab HMA w/ OGFC (20 yr)									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	8 / 4,400		20 / 5,600									
		3	Year of Action	0		10									
			Activity Description	**CAPM HMA w/ OGFC**		CAPM HMA w/ OGFC									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 3,700		10 / 6,800									
Rehabilitation															
HMA w/ OGFC	20	1,2,3	Year of Action	0				20		28				48	
			Activity Description	**Rehab HMA w/ OGFC (20 yr)**				CAPM HMA w/ OGFC		Rehab HMA w/ OGFC (20 yr)				CAPM HMA w/ OGFC	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 5,600				8 / 4,400		20 / 3,600				8 / 4,400	
			Year of Action	0											
			Activity Description	**New / Reconstruct**	Select a HMA w/ OGFC schedule for New Construction/Reconstruction from this M&R table										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	40	1,2,3	Year of Action	0								38		46	
			Activity Description	**Rehab HMA w/ OGFC (40 yr)**								CAPM HMA w/ OGFC		Lane Replace (40 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	38 / 5,200								8 / 4,400		40 / 6,400	
			Year of Action	0											
			Activity Description	**New / Reconstruct**	Select a HMA w/ OGFC schedule for New Construction/Reconstruction from this M&R table										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-2 (c)
Inland Valley Climate Region
HOT MIX ASPHALT W/ RHMA PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA w/ RHMA	20	1,2	Year of Action	0					21		31				52
			Activity Description	**New / Reconstruct**					CAPM HMA w/ RHMA		Rehab HMA w/ RHMA (20 yr)				CAPM HMA w/ RHMA
			Activity Service Life (years)	21					10		21				10
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,000					3,700		2,000				3,700
		3	Year of Action	0					21		31		41		51
			Activity Description	**New / Reconstruct**					CAPM HMA w/ RHMA		CAPM HMA w/ RHMA		CAPM HMA w/ RHMA		Lane Replace (20 yr)
			Activity Service Life (years)	21					10		10		10		21
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,000					3,700		6,800		6,800		3,000
	40	1,2	Year of Action	0								40		50	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ RHMA		Rehab HMA w/ RHMA (20 yr)	
			Activity Service Life (years)	40								10		21	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	7,200								3,700		3,400	
		3	Year of Action	0								40		50	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ RHMA		CAPM HMA w/ RHMA	
			Activity Service Life (years)	40								10		10	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	7,200								3,700		3,700	
CAPM															
HMA w/ RHMA	5+	1,2	Year of Action	0		10									
			Activity Description	**CAPM HMA w/ RHMA**		Rehab HMA w/ RHMA (20 yr)									
			Activity Service Life (years)	10		21									
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,700		3,400									
		3	Year of Action	0		10									
			Activity Description	**CAPM HMA w/ RHMA**		CAPM HMA w/ RHMA									
			Activity Service Life (years)	10		10									
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,700		6,800									
Rehabilitation															
HMA w/ RHMA	20	1,2,3	Year of Action	0					21		31				52
			Activity Description	**Rehab HMA w/ RHMA (20 yr)**					CAPM HMA w/ RHMA		Rehab HMA w/ RHMA (20 yr)				CAPM HMA w/ RHMA
			Activity Service Life (years)	21					10		21				10
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,400					3,700		3,400				3,700
			Year of Action	0	Select a HMA w/ RHMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	40	1,2,3	Year of Action	0								40		50	
			Activity Description	**Rehab HMA w/ RHMA (40 yr)**								CAPM HMA w/ RHMA		Lane Replace (40 yr)	
			Activity Service Life (years)	40								10		40	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	7,000								3,700		6,800	
			Year of Action	0	Select a HMA w/ RHMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-2 (d)
Inland Valley Climate Region
RUBBERIZED HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
RHMA	20	1,2	Year of Action	0					21	26				47	52
			Activity Description	**New / Reconstruct**					CAPM RHMA	Rehab RHMA (20 yr)				CAPM RHMA	Rehab RHMA (20 yr)
			Activity Service Life (years)	21					5	21				5	21
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,200					1,100	2,600				1,100	2,600
		3	Year of Action	0					21	30		39		47	
			Activity Description	**New / Reconstruct**					CAPM RHMA	CAPM RHMA		CAPM RHMA		Lane Replace (20 yr)	
			Activity Service Life (years)	21					9	9		8		21	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,200					4,400	4,400		5,100		2,200	
CAPM															
RHMA	5+	1,2	Year of Action	0	5										
			Activity Description	**CAPM RHMA**	Rehab RHMA (20 yr)										
			Activity Service Life (years)	5	21										
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,100	2,600										
		3	Year of Action	0		9		18							
			Activity Description	**CAPM RHMA**		CAPM RHMA		CAPM RHMA							
			Activity Service Life (years)	9		9		5							
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	4,400		4,400		5,100							
Rehabilitation															
RHMA	20	1,2,3	Year of Action	0					21	26				47	52
			Activity Description	**Rehab RHMA (20 yr)**					CAPM RHMA	Rehab RHMA (20 yr)				CAPM RHMA	Rehab RHMA (20 yr)
			Activity Service Life (years)	21					5	21				5	21
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,600					1,100	2,600				1,100	2,600
			Year of Action	0	Select a RHMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-2 (e)
Inland Valley Climate Region
RUBBERIZED HOT MIX ASPHALT W/ RHMA-O PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5		10		15		20		25		30		35		40		45		50		55	
New Construction/Reconstruction																												
RHMA w/ RHMA-O	20	1,2	Year of Action		0										22				32								54	
			Activity Description		New / Reconstruct										CAPM RHMA w/ RHMA-O				Rehab RHMA w/ RHMA-O (20 yr)								CAPM RHMA w/ RHMA-O	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,900									10	3,700			22	3,800							10	3,700
		3	Year of Action		0										22				32				42				53	
			Activity Description		New / Reconstruct										CAPM RHMA w/ RHMA-O				CAPM RHMA w/ RHMA-O				CAPM RHMA w/ RHMA-O				Lane Replace (20 yr)	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,900									10	3,400			10	6,300			11	6,300			21	6,300
	40	1,2	Year of Action		2900																40				50			
			Activity Description		New / Reconstruct																CAPM RHMA w/ RHMA-O				Rehab RHMA w/ RHMA-O (20 yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	4,900															10	3,700			22	3,800		
		3	Year of Action		0																40				50			
			Activity Description		New / Reconstruct																CAPM RHMA w/ RHMA-O				CAPM RHMA w/ RHMA-O			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	4,900															10	3,400			10	3,400		
CAPM																												
RHMA w/ RHMA-O	5+	1,2	Year of Action		0				10																			
			Activity Description		CAPM RHMA w/ RHMA-O				Rehab RHMA w/ RHMA-O (20 yr)																			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,400			22	3,800																		
		3	Year of Action		0				10																			
			Activity Description		CAPM RHMA w/ RHMA-O				CAPM RHMA w/ RHMA-O																			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,400			10	3,400																		
Rehabilitation																												
RHMA w/ RHMA-O	20	1,2,3	Year of Action		0										22				32								54	
			Activity Description		Rehab RHMA w/ RHMA-O (20 yr)										CAPM RHMA w/ RHMA-O				Rehab RHMA w/ RHMA-O (20 yr)								CAPM RHMA w/ RHMA-O	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	3,800									10	3,700			22	3,800							10	3,700
			Year of Action		0																							
			Activity Description		New / Reconstruct		Select a RHMA w/ RHMA-O schedule for New Construction/Reconstruction from this M&R table																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life																								
	40	1,2,3	Year of Action		0																40				50			
			Activity Description		Rehab RHMA w/ RHMA-O (40 yr)																CAPM RHMA w/ RHMA-O				Lane Replace (40 yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	5,100															10	3,700			40	4,900		
			Year of Action		0																							
			Activity Description		New / Reconstruct		Select a RHMA w/ RHMA-O schedule for New Construction/Reconstruction from this M&R table																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life																								

TABLE F-3 (a)
Desert Climate Region
HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA	20	1,2	Year of Action	0				18	23				41	46	
			Activity Description	**New / Reconstruct**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years)	18				5	18				5	18	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,600				1,100	3,000				1,100	3,000	
		3	Year of Action	0				18	25		31	37			
			Activity Description	**New / Reconstruct**				CAPM HMA	CAPM HMA		CAPM HMA	Lane Replace (20 yr)			
			Activity Service Life (years)	18				7	6		6	18			
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,600				5,700	5,700		6,800	3,600			
CAPM															
HMA	5+	1,2	Year of Action	0	5										
			Activity Description	**CAPM HMA**	Rehab HMA (20 yr)										
			Activity Service Life (years)	5	18										
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,100	3,000										
		3	Year of Action	0		7	14								
			Activity Description	**CAPM HMA**		CAPM HMA	CAPM HMA								
			Activity Service Life (years)	7		7	6								
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	5,700		5,500	6,800								
Rehabilitation															
HMA	20	1,2,3	Year of Action	0				18	23				41	46	
			Activity Description	**Rehab HMA (20 yr)**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years)	18				5	18				5	18	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,000				1,100	3,000				1,100	3,000	
			Year of Action	0	Select a HMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-3 (b)
Desert Climate Region
HOT MIX ASPHALT W/ OGFC PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA w/ OGFC	20	1,2	Year of Action	0				20		28				48	
			Activity Description	**New / Reconstruct**				CAPM HMA w/ OGFC		Rehab HMA w/ OGFC (20 yr)				CAPM HMA w/ OGFC	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 4,900				8 / 4,600		20 / 4,000				8 / 4,500	
		3	Year of Action	0				20		29		38		47	
			Activity Description	**New / Reconstruct**				CAPM HMA w/ OGFC		CAPM HMA w/ OGFC		CAPM HMA w/ OGFC		Lane Replace (20 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 4,900				9 / 4,000		9 / 7,400		9 / 7,400		20 / 4,900	
	40	1,2	Year of Action	0								38		47	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ OGFC		Rehab HMA w/ OGFC (20-yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	38 / 6,700								9 / 4,100		20 / 4,000	
		3	Year of Action	0								38		47	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ OGFC		CAPM HMA w/ OGFC	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	38 / 6,700								8 / 4,100		9 / 7,400	
CAPM															
HMA w/ OGFC	5+	1,2	Year of Action	0		8									
			Activity Description	**CAPM HMA w/ OGFC**		Rehab HMA w/ OGFC (20 yr)									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	8 / 4,600		20 / 4,000									
		3	Year of Action	0		9		18							
			Activity Description	**CAPM HMA w/ OGFC**		CAPM HMA w/ OGFC		CAPM HMA w/ OGFC							
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	9 / 4,000		9 / 7,400		9 / 7,400							
Rehabilitation															
HMA w/ OGFC	20	1,2,3	Year of Action	0				20		28				48	
			Activity Description	**Rehab HMA w/ OGFC (20 yr)**				CAPM HMA w/ OGFC		Rehab HMA w/ OGFC (20 yr)				CAPM HMA w/ OGFC	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 4,000				8 / 4,600		20 / 4,000				8 / 7,300	
			Year of Action	0											
			Activity Description	**New / Reconstruct**						Select a HMA w/ OGFC schedule for New Construction/Reconstruction from this M&R table					
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	40	1,2,3	Year of Action	0								38		46	
			Activity Description	**Rehab HMA w/ OGFC (40 yr)**								CAPM HMA w/ OGFC		Lane Replace (40 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	38 / 7,300								8 / 4,600		38 / 4,000	
			Year of Action	0											
			Activity Description	**New / Reconstruct**						Select a HMA w/ OGFC schedule for New Construction/Reconstruction from this M&R table					
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-3 (c)
Desert Climate Region
HOT MIX ASPHALT W/ RHMA PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5		10		15		20		25		30		35		40		45		50		55	
New Construction/Reconstruction																												
HMA w/ RHMA	20	1,2	Year of Action		0										21		30										51	
			Activity Description		**New / Reconstruct**										CAPM HMA w/ RHMA		Rehab HMA w/ RHMA (20 yr)										CAPM HMA w/ RHMA	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	21	5,400									9	4,000	21	3,700									9	5,400
		3	Year of Action		0										21				31				41				51	
			Activity Description		**New / Reconstruct**										CAPM HMA w/ RHMA				CAPM HMA w/ RHMA				CAPM HMA w/ RHMA				Lane Replace (20 yr)	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	21	3,300									10	3,700			10	7,900			10	7,900			21	3,300
	40	1,2	Year of Action		0																40				49			
			Activity Description		**New / Reconstruct**																CAPM HMA w/ RHMA				Rehab HMA w/ RHMA (20-yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	5,400															9	4,000			21	4,300		
		3	Year of Action		0																40				49			
			Activity Description		**New / Reconstruct**																CAPM HMA w/ RHMA				CAPM HMA w/ RHMA			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	5,400															9	4,000			9	4,000		
CAPM																												
HMA w/ RHMA	5+	1,2	Year of Action		0				9																			
			Activity Description		**CAPM HMA w/ RHMA**				Rehab HMA w/ RHMA (20 yr)																			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	9	4,100			21	3,700																		
		3	Year of Action		0				10																			
			Activity Description		**CAPM HMA w/ RHMA**				CAPM HMA w/ RHMA																			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	3,700			10	7,900																		
Rehabilitation																												
HMA w/ RHMA	20	1,2,3	Year of Action		0										21		30										51	
			Activity Description		**Rehab HMA w/ RHMA (20 yr)**										CAPM HMA w/ RHMA		Rehab HMA w/ RHMA (20 yr)										CAPM HMA w/ RHMA	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	21	3,700									9	4,100	21	3,700									9	4,100
			Year of Action		0																							
			Activity Description		**New / Reconstruct**		Select a HMA w/ RHMA schedule for New Construction/Reconstruction from this M&R table																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over																								
	40	1,2,3	Year of Action		0																40				49			
			Activity Description		**Rehab HMA w/ RHMA (40 yr)**																CAPM HMA w/ RHMA				Lane Replace (40 yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	40	5,900															9	4,000			40	5,400		
			Year of Action		0																							
			Activity Description		**New / Reconstruct**		Select a HMA w/ RHMA schedule for New Construction/Reconstruction from this M&R table																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life																								

TABLE F-3 (d)
Desert Climate Region
RUBBERIZED HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
RHMA	20	1,2	Year of Action	0				20	25				45	50	
			Activity Description	**New / Reconstruct**				CAPM RHMA	Rehab RHMA (20 yr)				CAPM RHMA	Rehab RHMA (20 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 2,500				5 / 1,100	20 / 3,500				5 / 1,100	20 / 3,500	
		3	Year of Action	0				20		27	34		41		
			Activity Description	**New / Reconstruct**				CAPM RHMA		CAPM RHMA	CAPM RHMA		Lane Replace (20 yr)		
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 2,500				7 / 2,900		7 / 5,500	7 / 5,700		20 / 2,500		
CAPM															
RHMA	5+	1,2	Year of Action	0	5										
			Activity Description	**CAPM RHMA**	Rehab RHMA (20 yr)										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 / 1,100	20 / 3,500										
		3	Year of Action	0		7	14								
			Activity Description	**CAPM RHMA**		CAPM RHMA	CAPM RHMA								
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	7 / 5,500		7 / 5,500	7 / 5,700								
Rehabilitation															
RHMA	20	1,2,3	Year of Action	0				20	25				45	50	
			Activity Description	**Rehab RHMA (20 yr)**				CAPM RHMA	Rehab RHMA (20 yr)				CAPM RHMA	Rehab RHMA (20 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 3,500				5 / 1,100	20 / 3,500				5 / 1,100	20 / 3,500	
			Year of Action	0	Select a RHMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-3 (e)
Desert Climate Region
RUBBERIZED HOT MIX ASPHALT W/ RHMA-O PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
RHMA w/ RHMA-O	20	1,2	Year of Action	0					22		32				54
			Activity Description	**New / Reconstruct**					CAPM RHMA w/ RHMA-O		Rehab RHMA w/ RHMA-O (20 yr)				CAPM RHMA w/ RHMA-O
			Activity Service Life (years)	22					10		22				10
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,100					3,700		3,900				3,700
		3	Year of Action	0					22		33		44		55
			Activity Description	**New / Reconstruct**					CAPM RHMA w/ RHMA-O		CAPM RHMA w/ RHMA-O		CAPM RHMA w/ RHMA-O		Lane Replace (20 yr)
			Activity Service Life (years)	22					11		11		11		22
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,100					3,400		3,400		6,800		3,100
	40	1,2	Year of Action	0								40		50	
			Activity Description	**New / Reconstruct**								CAPM RHMA w/ RHMA-O		Rehab RHMA w/ RHMA-O (20-yr)	
			Activity Service Life (years)	40								10		22	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	4,500								3,700		4,500	
		3	Year of Action	0								40			51
			Activity Description	**New / Reconstruct**								CAPM RHMA w/ RHMA-O			CAPM RHMA w/ RHMA-O
			Activity Service Life (years)	40								11			11
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	4,500								3,400			4,500
CAPM															
RHMA w/ RHMA-O	5+	1,2	Year of Action	0		10									
			Activity Description	**CAPM RHMA w/ RHMA-O**		Rehab RHMA w/ RHMA-O (20 yr)									
			Activity Service Life (years)	10		22									
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,700		3,900									
		3	Year of Action	0			11								
			Activity Description	**CAPM RHMA w/ RHMA-O**			CAPM RHMA w/ RHMA-O								
			Activity Service Life (years)	11			11								
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,400			4,500								
Rehabilitation															
RHMA w/ RHMA-O	20	1,2,3	Year of Action	0					22		32				54
			Activity Description	**Rehab RHMA w/ RHMA-O (20 yr)**					CAPM RHMA w/ RHMA-O		Rehab RHMA w/ RHMA-O (20 yr)				CAPM RHMA w/ RHMA-O
			Activity Service Life (years)	22					10		22				10
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,900					3,700		3,900				3,700
			Year of Action	0	Select a RHMA w/ RHMA-O schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	40	1,2,3	Year of Action	0								40		50	
			Activity Description	**Rehab RHMA w/ RHMA-O (40 yr)**								CAPM RHMA w/ RHMA-O		Lane Replace (40 yr)	
			Activity Service Life (years)	40								10		40	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	6,100								3,700		4,500	
			Year of Action	0	Select a RHMA w/ RHMA-O schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-4 (a)
Low Mountain & South Mountain Climate Regions
HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA	20	1,2	Year of Action	0				19	24				43	48	
			Activity Description	**New / Reconstruct**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years)	19				5	19				5	19	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,500				1,100	2,800				1,100	2,800	
		3	Year of Action	0				19		28		37	45		
			Activity Description	**New / Reconstruct**				CAPM HMA		CAPM HMA		CAPM HMA	Lane Replace (20 yr)		
			Activity Service Life (years)	19				9		9		8	19		
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,500				5,700		5,700		5,600	3,500		
CAPM															
HMA	5+	1,2	Year of Action	0	5										
			Activity Description	**CAPM HMA**	Rehab HMA (20 yr)										
			Activity Service Life (years)	5	19										
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,100	2,600										
		3	Year of Action	0		9		18							
			Activity Description	**CAPM HMA**		CAPM HMA		CAPM HMA							
			Activity Service Life (years)	9		9		8							
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	5,700		5,700		5,600							
Rehabilitation															
HMA	20	1,2,3	Year of Action	0				19	24				43	48	
			Activity Description	**Rehab HMA (20 yr)**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years)	19				5	19				5	19	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,600				1,100	2,600				1,100	2,600	
			Year of Action	0	Select a HMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-4 (b)
Low Mountain & South Mountain Climate Regions
HOT MIX ASPHALT W/ OGFC PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA w/ OGFC	20	1,2	Year of Action	0					22	28				50	
			Activity Description	**New / Reconstruct**					CAPM HMA w/ OGFC	Rehab HMA w/ OGFC (20 yr)				CAPM HMA w/ OGFC	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	22 / 2,700					6 / 500	22 / 3,700				6 / 500	
		3	Year of Action	0					22		32		42		52
			Activity Description	**New / Reconstruct**					CAPM HMA w/ OGFC		CAPM HMA w/ OGFC		CAPM HMA w/ OGFC		Lane Replace (20 yr)
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	22 / 2,700					10 / 4,800		10 / 6,800		10 / 6,800		20 / 2,700
	40	1,2	Year of Action	0								40		46	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ OGFC		Rehab HMA w/ OGFC (20-yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 7,500								6 / 500		22 / 2,700	
		3	Year of Action	0								40		50	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ OGFC		CAPM HMA w/ OGFC	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 7,500								10 / 6,800		10 / 6,800	
CAPM															
HMA w/ OGFC	5+	1,2	Year of Action	0		6									
			Activity Description	**CAPM HMA w/ OGFC**		Rehab HMA w/ OGFC (20 yr)									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	6 / 500		22 / 3,700									
		3	Year of Action	0		10									
			Activity Description	**CAPM HMA w/ OGFC**		CAPM HMA w/ OGFC									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 4,800		10 / 6,800									
Rehabilitation															
HMA w/ OGFC	20	1,2,3	Year of Action	0					22	28				50	
			Activity Description	**Rehab HMA w/ OGFC (20 yr)**					CAPM HMA w/ OGFC	Rehab HMA w/ OGFC (20 yr)				CAPM HMA w/ OGFC	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	22 / 3,700					6 / 500	22 / 3,600				6 / 500	
			Year of Action	0	Select a HMA w/ OGFC schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	40	1,2,3	Year of Action	0								40		46	
			Activity Description	**Rehab HMA w/ OGFC (40 yr)**								CAPM HMA w/ OGFC		Lane Replace (40 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 7,800								6 / 500		40 / 7,500	
			Year of Action	0	Select a HMA w/ OGFC schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-4 (c)
Low Mountain & South Mountain Climate Regions
HOT MIX ASPHALT W/ RHMA PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA w/ RHMA	20	1,2	Year of Action	0					23	30					53
			Activity Description	**New / Reconstruct**					CAPM HMA w/ RHMA	Rehab HMA w/ RHMA (20 yr)					CAPM HMA w/ RHMA
			Activity Service Life (years)	23					7	23					7
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,000					800	3,900					800
		3	Year of Action	0					23		33		43		53
			Activity Description	**New / Reconstruct**					CAPM HMA w/ RHMA		CAPM HMA w/ RHMA		CAPM HMA w/ RHMA		Lane Replace (20 yr)
			Activity Service Life (years)	23					10		10		10		23
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,000					600		5,300		5,300		3,000
	40	1,2	Year of Action	0								40		47	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ RHMA		Rehab HMA w/ RHMA (20-yr)	
			Activity Service Life (years)	40								7		23	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	5,000								800		3,000	
		3	Year of Action	0								40		50	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ RHMA		CAPM HMA w/ RHMA	
			Activity Service Life (years)	40								10		10	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	5,000								600		5,300	
CAPM															
HMA w/ RHMA	5+	1,2	Year of Action	0		7									
			Activity Description	**CAPM HMA w/ RHMA**		Rehab HMA w/ RHMA (20 yr)									
			Activity Service Life (years)	7		23									
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	800		4,000									
		3	Year of Action	0		10									
			Activity Description	**CAPM HMA w/ RHMA**		CAPM HMA w/ RHMA									
			Activity Service Life (years)	10		10									
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	600		5,100									
Rehabilitation															
HMA w/ RHMA	20	1,2,3	Year of Action	0					23	30					53
			Activity Description	**Rehab HMA w/ RHMA (20 yr)**					CAPM HMA w/ RHMA	Rehab HMA w/ RHMA (20 yr)					CAPM HMA w/ RHMA
			Activity Service Life (years)	23					7	23					7
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	4,000					800	4,300					800
			Year of Action	0	Select a HMA w/ RHMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	40	1,2,3	Year of Action	0								40		47	
			Activity Description	**Rehab HMA w/ RHMA (40 yr)**								CAPM HMA w/ RHMA		Lane Replace (40 yr)	
			Activity Service Life (years)	40								7		40	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	5,400								800		5,000	
			Year of Action	0	Select a HMA w/ RHMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-4 (d)
Low Mountain & South Mountain Climate Regions
RUBBERIZED HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5		10		15		20		25		30		35		40		45		50		55	
New Construction/Reconstruction																												
RHMA	20	1,2	Year of Action		0										21		26								47		52	
			Activity Description		**New / Reconstruct**										CAPM RHMA		Rehab RHMA (20 yr)								CAPM RHMA		Rehab RHMA (20 yr)	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	21	2,300									5	1,100	21	2,600							5	1,100	21	2,600
		3	Year of Action		0										21		30				39				47			
			Activity Description		**New / Reconstruct**										CAPM RHMA		CAPM RHMA				CAPM RHMA				Lane Replace (20 yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	21	2,300									9	4,400	9	4,400			8	4,900			21	2,300		
CAPM																												
RHMA	5+	1,2	Year of Action		0		5																					
			Activity Description		**CAPM RHMA**		Rehab RHMA (20 yr)																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	1,100	21	2,600																				
		3	Year of Action		0				9				18															
			Activity Description		**CAPM RHMA**				CAPM RHMA (10 yr)				CAPM RHMA															
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	9	4,400			9	4,400			8	4,900														
Rehabilitation																												
RHMA	20	1,2,3	Year of Action		0										21		26								47		52	
			Activity Description		**Rehab RHMA (20 yr)**										CAPM RHMA		Rehab RHMA (20 yr)								CAPM RHMA		Rehab RHMA (20 yr)	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	21	2,600									5	1,100	21	2,600							5	1,100	21	2,600
			Year of Action		0																							
			Activity Description		**New / Reconstruct**		Select a RHMA schedule for New Construction/Reconstruction from this M&R table																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life																								

TABLE F-4 (e)
Low Mountain & South Mountain Climate Regions
RUBBERIZED HOT MIX ASPHALT W/ RHMA-O PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
RHMA w/ RHMA-O	20	1,2	Year of Action	0					24		32				
			Activity Description	**New / Reconstruct**					CAPM RHMA w/ RHMA-O		Rehab RHMA w/ RHMA-O (20 yr)				
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	24 / 2,600					8 / 700		24 / 3,500				
		3	Year of Action	0					24		34		44		54
			Activity Description	**New / Reconstruct**					CAPM RHMA w/ RHMA-O		CAPM RHMA w/ RHMA-O		CAPM RHMA w/ RHMA-O		Lane Replace (20 yr)
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	24 / 2,600					10 / 600		10 / 600		10 / 5,000		24 / 2,600
	40	1,2	Year of Action	0								40		48	
			Activity Description	**New / Reconstruct**								CAPM RHMA w/ RHMA-O		Rehab RHMA w/ RHMA-O (20-yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 3,900								8 / 700		24 / 4,100	
		3	Year of Action	0								40		50	
			Activity Description	**New / Reconstruct**								CAPM RHMA w/ RHMA-O		CAPM RHMA w/ RHMA-O	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 3,900								10 / 600		10 / 700	
CAPM															
RHMA w/ RHMA-O	5+	1,2	Year of Action	0		8									
			Activity Description	**CAPM RHMA w/ RHMA-O**		Rehab RHMA w/ RHMA-O (20 yr)									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	8 / 700		24 / 5,200									
		3	Year of Action	0		10									
			Activity Description	**CAPM RHMA w/ RHMA-O**		CAPM RHMA w/ RHMA-O									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 600		10 / 5,000									
Rehabilitation															
RHMA w/ RHMA-O	20	1,2,3	Year of Action	0					24		32				
			Activity Description	**Rehab RHMA w/ RHMA-O (20 yr)**					CAPM RHMA w/ RHMA-O		Rehab RHMA w/ RHMA-O (20 yr)				
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	24 / 5,200					8 / 700		24 / 3,500				
			Year of Action	0											
			Activity Description	**New / Reconstruct**	Select a RHMA w/ RHMA-O schedule for New Construction/Reconstruction from this M&R table										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	40	1,2,3	Year of Action	0								40		48	
			Activity Description	**Rehab RHMA w/ RHMA-O (40 yr)**								CAPM RHMA w/ RHMA-O		Lane Replace (40 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 3,100								8 / 700		40 / 3,900	
			Year of Action	0											
			Activity Description	**New / Reconstruct**	Select a RHMA w/ RHMA-O schedule for New Construction/Reconstruction from this M&R table										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-5 (a)
High Mountain & High Desert Climate Regions
HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA	20	1,2	Year of Action	0				18	23				41	46	
			Activity Description	**New / Reconstruct**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years)	18				5	18				5	18	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,300				1,100	2,300				1,300	900	
		3	Year of Action	0				18		26	34		42		
			Activity Description	**New / Reconstruct**				CAPM HMA		CAPM HMA	CAPM HMA		Lane Replace (20 yr)		
			Activity Service Life (years)	18				8		8	8		18		
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,300				3,500		7,700	7,700		2,200		
CAPM															
HMA	5+	1,2	Year of Action	0	5										
			Activity Description	**CAPM HMA**	Rehab HMA (20 yr)										
			Activity Service Life (years)	5	18										
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,100	2,300										
		3	Year of Action	0		8		16							
			Activity Description	**CAPM HMA**		CAPM HMA		CAPM HMA							
			Activity Service Life (years)	8		8		8							
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,500		7,700		7,700							
Rehabilitation															
HMA	20	1,2,3	Year of Action	0				18	23				41	46	
			Activity Description	**Rehab HMA (20 yr)**				CAPM HMA	Rehab HMA (20 yr)				CAPM HMA	Rehab HMA (20 yr)	
			Activity Service Life (years)	18				5	18				5	18	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	2,300				1,100	3,300				1,100	900	
			Year of Action	0	Select a HMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Description	**New / Reconstruct**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-5 (b)
High Mountain & High Desert Climate Regions
HOT MIX ASPHALT W/ RHMA PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
HMA w/ RHMA	20	1,2	Year of Action	0				20	25				45	50	
			Activity Description	**New / Reconstruct**				CAPM HMA w/ RHMA	Rehab HMA w/ RHMA (20 yr)				CAPM HMA w/ RHMA	Rehab HMA w/ RHMA (20 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 8,800				5 / 0	20 / 9,800				5 / 0	20 / 9,800	
		3	Year of Action	0				20		30		40		50	
			Activity Description	**New / Reconstruct**				CAPM HMA w/ RHMA		CAPM HMA w/ RHMA		CAPM HMA w/ RHMA		Lane Replace (20 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 8,800				10 / 5,900		10 / 7,900		10 / 7,900		20 / 8,800	
	40	1,2	Year of Action	0								40	45		
			Activity Description	**New / Reconstruct**								CAPM HMA w/ RHMA	Rehab HMA w/ RHMA (20 yr)		
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 12,300								5 / 0	20 / 9,800		
		3	Year of Action	0								40		50	
			Activity Description	**New / Reconstruct**								CAPM HMA w/ RHMA		CAPM HMA w/ RHMA	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 12,300								10 / 5,900		10 / 5,900	
CAPM															
HMA w/ RHMA	5+	1,2	Year of Action	0	5										
			Activity Description	**CAPM HMA w/ RHMA**	Rehab HMA w/ RHMA (20 yr)										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 / 0	20 / 9,800										
		3	Year of Action	0		10									
			Activity Description	**CAPM HMA w/ RHMA**		CAPM HMA w/ RHMA									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 5,900		10 / 7,900									
Rehabilitation															
HMA w/ RHMA	20	1,2,3	Year of Action	0				20	25				45	50	
			Activity Description	**Rehab HMA w/ RHMA (20 yr)**				CAPM HMA w/ RHMA	Rehab HMA w/ RHMA (20 yr)				CAPM HMA w/ RHMA	Rehab HMA w/ RHMA (20 yr)	
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	20 / 9,800				5 / 0	20 / 9,800				5 / 0	20 / 9,800	
			Year of Action	0											
			Activity Description	**New / Reconstruct**	Select a HMA w RHMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	40	1,2,3	Year of Action	0								40	45		
			Activity Description	**Rehab HMA w/ RHMA (40 yr)**								CAPM HMA w/ RHMA	Lane Replace (40 yr)		
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	40 / 14,300								5 / 0	40 / 12,300		
			Year of Action	0											
			Activity Description	**New / Reconstruct**	Select a HMA w RHMA schedule for New Construction/Reconstruction from this M&R table										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												

TABLE F-5 (c)
High Mountain & High Desert Climate Regions
RUBBERIZED HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5		10		15		20		25		30		35		40		45		50		55	
New Construction/Reconstruction																												
RHMA	20	1,2	Year of Action		0								20		25								45		50			
			Activity Description		**New / Reconstruct**								CAPM RHMA		Rehab RHMA (20 yr)								CAPM RHMA		Rehab RHMA (20 yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	2,100							5	1,100	20	3,100							5	1,100	20	3,100		
		3	Year of Action		0								20				29				38				47			
			Activity Description		**New / Reconstruct**								CAPM RHMA				CAPM RHMA				CAPM RHMA				Lane Replace (20 yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	2,100							9	3,100			9	6,700			9	6,700			20	3,100		
CAPM																												
RHMA	5	1,2	Year of Action		0		5																					
			Activity Description		**CAPM RHMA**		Rehab RHMA (20 yr)																					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	5	1,100	20	3,100																				
		3	Year of Action		0				9				18															
			Activity Description		**CAPM RHMA**				CAPM RHMA				CAPM RHMA															
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	9	3,100			9	6,700			9	6,700														
Rehabilitation																												
RHMA	20	1,2,3	Year of Action		0								20				25						45		50			
			Activity Description		**Rehab RHMA (20 yr)**								CAPM RHMA				Rehab RHMA (20 yr)						CAPM RHMA		Rehab RHMA (20 yr)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	20	3,100							5	1,100			20	3,100					5	1,100	20	3,100		
			Year of Action		0		Select a RHMA schedule for New Construction/Reconstruction from this M&R table																					
			Activity Description		**New / Reconstruct**																							
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life																								

TABLE R-1 (a)

Inland Valley, Dessert, Low Mountain, South Mountain, and all Coastal Climate Regions

RIGID AND COMPOSITE PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Pavement Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5		10		15		20		25		30		35		40		45		50		55	
New Construction/Reconstruction																												
Composite	20	1,2,3	Year of Action		0												30				38		45		Select a lane replace option listed under the rigid and composite pavement M&R table and follow the strategy sequence			
			Activity Description		**New / Reconstruct**												CAPM (FO+ JPCP SR)				CAPM (FO+ JPCP SR)		Lane Replace					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	30	4,100											8	700			7	800						
	40	1,2,3	Year of Action		0																				50			
			Activity Description		**New / Reconstruct**																				CAPM (FO+ JPCP SR)			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	50	4,800																			8	700		
Rigid - Jointed Plain Concrete Pavement (JPCP)	20	1,2,3	Year of Action		0										25		30				40		45		Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence			
			Activity Description		**New / Reconstruct**										CAPM (CPR C[3])		CAPM (CPR B[2])				CAPM (CPR A[1])		Roadway Rehab					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	25	700									5	3,000	10	1,500			5	3,100						
	40	1,2,3	Year of Action		0																		45		50			
			Activity Description		**New / Reconstruct**																		CAPM (CPR C[3])		CAPM (CPR B[2])			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	45	800																	5	3,000	10	1,500		
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	20	1,2,3	Year of Action		0												30		35				45					
			Activity Description		**New / Reconstruct**												CAPM (PR C[7])		CAPM (PR B[6])				CAPM (PR A[5])					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	30	200											5	1,400	10	600			10	600				
	40	1,2,3	Year of Action		0																				50			
			Activity Description		**New / Reconstruct**																				CAPM (PR C[7])			
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	50	200																			5	1,400		

CPR = Concrete Pavement Rehabilitation, CSFOL = Crack, Seat, and Flexible Overlay, FO = Flexible Overlay, MSRO = Mill, Slab Replacement & Overlay, PR = Punchout Repair, SR = Slab Replacement

Notes:

1. Concrete Pavement Rehabilitation A involves pavement grinding, **significant** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs that were replaced or exhibit third stage Rigid Cracking greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.
2. Concrete Pavement Rehabilitation B involves pavement grinding, **moderate** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking between 2 and 5%.
3. Concrete Pavement Rehabilitation C involves pavement grinding, **minor** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking 2% or less.
4. The schedule for this strategy is based on pavement that has previously been cracked, seated and overlaid. It should not be used as an alternative on rigid JPCP pavements with cracking or faulting near or above the threshold for roadway rehabilitation.
5. Punchout Repair A involves **significant** punchout repairs & 0.15' of flexible overlay. It applies to **continuously reinforced concrete pavements** that had previous punchout repairs and a flexible overlay.
6. Punchout Repair B involves **moderate** punchout repairs & 0.15' of flexible overlay. It applies to **continuously reinforced concrete pavements** where the total number of current & previous punchout repairs exceed 4 per mile.
7. Punchout Repair C involves **minor** punchout repairs & limited diamond grinding around the punchout repair area. It applies to **continuously reinforced concrete pavements** where the total number of punchout repairs do not exceed 4 per mile.

TABLE R-1 (b)
Inland Valley, Dessert, Low Mountain, South Mountain, and all Coastal Climate Regions
RIGID AND COMPOSITE PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Pavement Type	Pvmt Design Life	Maint. Service Level	Year	0	5	10	15	20	25	30	35	40	45	50	55
CAPM															
Slab Replacement (CPR[3])	10	1,2,3	Year of Action	0		10	15	20							
			Activity Description	CAPM (CPR C[3])		CAPM (CPR B[2])	CAPM (CPR A[1])	Roadway Rehab[4]	Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence						
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 2,098		5 4135	5 4,135								
Composite	5	1,2,3	Year of Action	0											
			Activity Description	**CAPM (Flex Overlay)**	The maintenance and rehabilitation schedules depend on the previous history and condition of the existing pavement. To determine the appropriate M&R schedule to use, first determine the initial pavement type and the original rehabilitation completed. Next, determined any other rehabilitations and/or CAPM projects completed after the initial rehabilitation. Ignore projects that only removed and replaced RHMA-G or RHMA-O. Finally, find a schedule on the rehabilitation M&R table that best describes the original rehabilitation completed and that sequence. However, from the pavement history, take into consideration the activities already completed in that sequence.										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	5	1,2,3	Year of Action	0											
			Activity Description	**CAPM (FO + JPCP SR)**	EXAMPLE: You are doing a Flexible Overlay and JPCP Slab Replacement on a previously cracked, seated, and overlaid project (doesn't matter whether it was 10 or 20 year). Previous work included a remove and replace RHMA-O 7 years after the crack, seat, and flexible overlay (CSFOL) rehabilitation, and a 0.10' HMA overlay at 18 years after the CSFOL project. From this information it can be determined that the initial pavement type was rigid and the original rehabilitation completed was a CSFOL. If the RHMA-O project at year 7 is ignored, it can be determined that the best fit for this sequence is the 20-year CSFOL. The 0.10' HMA overlay at 18 years after the completion of the CSFOL is the first CAPM under this sequence and the future activities will include a CAPM (FO + JPCP SR) at Year 23 and a 20-year rehab at Year 28. Remember to follow the sequence until you fulfill the analysis period.										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												
Rigid - Jointed Plain Concrete Pavement (JPCP)	5	1,2,3	Year of Action	0	5										
			Activity Description	**CAPM (CPR A[1])**	Roadway Rehab	Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 3,100											
	10	1,2,3	Year of Action	0		10	15								
			Activity Description	**CAPM (CPR B[2])**		CAPM (CPR A[1])	Roadway Rehab	Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence							
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 1,500		5 3,100									
	5	1,2,3	Year of Action	0	5		15								
			Activity Description	**CAPM (CPR C[3])**	CAPM (CPR B[2])		CAPM (CPR A[1])								
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 3,000	10 1,500		5 3,100								
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	5	1,2,3	Year of Action	0		10									
			Activity Description	**CAPM (PR A[5])**		Lane Replace with CRCP	Select a lane replace option listed under the rigid and composite pavement M&R table and follow the strategy sequence								
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 600											
	10	1,2,3	Year of Action	0		10									
			Activity Description	**CAPM (PR B[6])**		CAPM (PR A[5])									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 600		10 600									
	10	1,2,3	Year of Action	0	5		15								
			Activity Description	**CAPM (PR C[7])**	CAPM (PR B[6])		CAPM (PR A[5])								
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 1,400	10 600		10 600								

CPR = Concrete Pavement Rehabilitation, CSFOL = Crack, Seat, and Flexible Overlay, FO = Flexible Overlay, MSRO = Mill, Slab Replacement & Overlay, PR = Punchout Repair, SR = Slab Replacement

Notes:

1. Concrete Pavement Rehabilitation A involves pavement grinding, **significant** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs that were replaced or exhibit third stage Rigid Cracking greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.
2. Concrete Pavement Rehabilitation B involves pavement grinding, **moderate** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking between 2 and 5%.
3. Concrete Pavement Rehabilitation C involves pavement grinding, **minor** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking 2% or less.
4. The schedule for this strategy is based on pavement that has previously been cracked, seated and overlaid. It should not be used as an alternative on rigid JPCP pavements with cracking or faulting near or above the threshold for roadway rehabilitation.
5. Punchout Repair A involves **significant** punchout repairs & 0.15' of flexible overlay. It applies to **continuously reinforced concrete pavements** that had previous punchout repairs and a flexible overlay.
6. Punchout Repair B involves **moderate** punchout repairs & 0.15' of flexible overlay. It applies to **continuously reinforced concrete pavements** where the total number of current & previous punchout repairs exceed 4 per mile.
7. Punchout Repair C involves **minor** punchout repairs & limited diamond grinding around the punchout repair area. It applies to **continuously reinforced concrete pavements** where the total number of punchout repairs do not exceed 4 per mile.

TABLE R-1 (c)
Inland Valley, Dessert, Low Mountain, South Mountain, and all Coastal Climate Regions
RIGID AND COMPOSITE PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Pavement Type	Pvmt Design Life	Maint. Service Level	Year	0	5	10	15	20	25	30	35	40	45	50	55
Rehabilitation (a)															
Flexible/ composite	20	1,2,3	Year of Action	0				18	23	28				46	51
			Activity Description	**20-yr Rehab (CSFOL)**				CAPM (Flex Overlay)	CAPM (FO + JPCP SR)	20-yr Rehab (MSRO)				CAPM (FO + JPCP SR)	CAPM (FO + JPCP SR)
			Activity Service Life (years)	18				5	5	18				5	7
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,400				1,100	1,100	1,400				1,100	800
	20	1,2,3	Year of Action	0				18	23	30	Select a lane replace option listed under the rigid and composite pavement M&R table and follow the strategy sequence				
			Activity Description	**20-yr Rehab (MSRO)**				CAPM (FO + JPCP SR)	CAPM (FO + JPCP SR)	Lane Replace					
			Activity Service Life (years)	18				5	7						
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	1,400				1,100	800						
	20 & 40	1,2,3	Year of Action	0	Follow the strategies for new construction/reconstruction in the applicable flexible pavement tables for the appropriate climate region										
			Activity Description	**Lane Replace**											
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	20	1,2,3	Year of Action	0						30		38	45	Select a lane replace option listed under the rigid and composite pavement M&R table and follow the strategy sequence	
			Activity Description	**20-yr Rehab (Lane Replace)**						CAPM (FO+ JPCP SR)		CAPM (FO+ JPCP SR)	Lane Replace		
			Activity Service Life (years)	30						8		7			
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	4,100						700		800			
	40	1,2,3	Year of Action	0										50	
			Activity Description	**40-yr Rehab (Lane Replace)**										CAPM (FO+ JPCP SR)	
			Activity Service Life (years)	50										8	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	4,800										700	

CPR = Concrete Pavement Rehabilitation, CSFOL = Crack, Seat, and Flexible Overlay, FO = Flexible Overlay, MSRO = Mill, Slab Replacement & Overlay, PR = Punchout Repair, SR = Slab Replacement

Notes:

1. Concrete Pavement Rehabilitation A involves pavement grinding, **significant** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs that were replaced or exhibit third stage Rigid Cracking greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.
2. Concrete Pavement Rehabilitation B involves pavement grinding, **moderate** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking between 2 and 5%.
3. Concrete Pavement Rehabilitation C involves pavement grinding, **minor** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking 2% or less.
4. The schedule for this strategy is based on pavement that has previously been cracked, seated and overlaid. It should not be used as an alternative on rigid JPCP pavements with cracking or faulting near or above the threshold for roadway rehabilitation.
5. Punchout Repair A involves **significant** punchout repairs & 0.15' of flexible overlay. It applies to **continuously reinforced concrete pavements** that had previous punchout repairs and a flexible overlay.
6. Punchout Repair B involves **moderate** punchout repairs & 0.15' of flexible overlay. It applies to **continuously reinforced concrete pavements** where the total number of current & previous punchout repairs exceed 4 per mile.
7. Punchout Repair C involves **minor** punchout repairs & limited diamond grinding around the punchout repair area. It applies to **continuously reinforced concrete pavements** where the total number of punchout repairs do not exceed 4 per mile.

TABLE R-1 (d)

Inland Valley, Dessert, Low Mountain, South Mountain, and all Coastal Climate Regions

RIGID AND COMPOSITE PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Pavement Type	Pvmt Design Life	Maint. Service Level	Year	0	5	10	15	20	25	30	35	40	45	50	55
Rehabilitation (b)															
Rigid - Jointed Plain Concrete Pavement (JPCP)	20	1,2,3	Year of Action	0					25	30		40	45	Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence	
			Activity Description	**20-yr Rehab (Lane Replace)**					CAPM (CPR C[3])	CAPM (CPR B[2])		CAPM (CPR A[1])	Roadway Rehab		
			Activity Service Life (years)	25					5	10		5			
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	700					3,000	1,500		3,100			
	40	1,2,3	Year of Action	0									45	50	
			Activity Description	**40-yr Rehab (Lane Replace)**									CAPM (CPR C[3])	CAPM (CPR B[2])	
			Activity Service Life (years)	45									5	10	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	800									3,000	1,500	
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	20	1,2,3	Year of Action	0						30	35		45		
			Activity Description	**20-yr Rehab (Lane Replace)**						CAPM (PR C[7])	CAPM (PR B[6])		CAPM (PR A[5])		
			Activity Service Life (years)	30						5	10		10		
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	200						1,400	600		600		
	40	1,2,3	Year of Action	0										50	
			Activity Description	**40-yr Rehab (Lane Replace)**										CAPM (PR C[7])	
			Activity Service Life (years)	50										5	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	200										1,400	

CPR = Concrete Pavement Rehabilitation, CSFOL = Crack, Seat, and Flexible Overlay, FO = Flexible Overlay, MSRO = Mill, Slab Replacement & Overlay, PR = Punchout Repair, SR = Slab Replacement

Notes:

1. Concrete Pavement Rehabilitation A involves pavement grinding, **significant** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs that were replaced or exhibit third stage Rigid Cracking greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

2. Concrete Pavement Rehabilitation B involves pavement grinding, **moderate** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking between 2 and 5%.

3. Concrete Pavement Rehabilitation C involves pavement grinding, **minor** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking 2% or less.

4. The schedule for this strategy is based on pavement that has previously been cracked, seated and overlaid. It should not be used as an alternative on rigid JPCP pavements with cracking or faulting near or above the threshold for roadway rehabilitation.

5. Punchout Repair A involves **significant** punchout repairs & 0.15' of flexible overlay. It applies to **continuously reinforced concrete pavements** that had previous punchout repairs and a flexible overlay.

6. Punchout Repair B involves **moderate** punchout repairs & 0.15' of flexible overlay. It applies to **continuously reinforced concrete pavements** where the total number of current & previous punchout repairs exceed 4 per mile.

7. Punchout Repair C involves **minor** punchout repairs & limited diamond grinding around the punchout repair area. It applies to **continuously reinforced concrete pavements** where the total number of punchout repairs do not exceed 4 per mile.

TABLE R-2 (a)

High Mountain and High Desert Climate Regions

RIGID AND COMPOSITE PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Pavement Type	Pvmt Design Life	Maint. Service Level	Year	Begin Alternative Construction	5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction															
Composite	20	1,2,3	Year of Action	0						30		40	45	Select a lane replace option listed under the rigid and composite pavement M&R table and follow the strategy sequence	
			Activity Description	**New / Reconstruct**						CAPM (FO+ JPCP SR)		CAPM (FO+ JPCP SR)	Lane Replace		
			Activity Service Life (years)	30						10		5			
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	7,300						5,900		1,100			
	40	1,2,3	Year of Action	0										50	
			Activity Description	**New / Reconstruct**										CAPM (FO+ JPCP SR)	
			Activity Service Life (years)	50										5	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	8,400										1,100	
Rigid - Jointed Plain Concrete Pavement (JPCP)	20	1,2,3	Year of Action	0					25	30		40	45	Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence	
			Activity Description	**New / Reconstruct**					CAPM (CPR C[3])	CAPM (CPR B[2])		CAPM (CPR A[1])	Roadway Rehab		
			Activity Service Life (years)	25					5	10		5			
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,100					3,000	1,500		3,100			
	40	1,2,3	Year of Action	0									45	50	
			Activity Description	**New / Reconstruct**									CAPM (CPR C[3])	CAPM (CPR B[2])	
			Activity Service Life (years)	45									5	5	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	3,800									3,000	1,500	

CPR = Concrete Pavement Rehabilitation, CSFOL = Crack, Seat, and Flexible Overlay, FO = Flexible Overlay, MSRO = Mill, Slab Replacement & Overlay, SR = Slab Replacement

Notes:

1. Concrete Pavement Rehabilitation A involves pavement grinding, **significant** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs that were replaced or exhibit third stage Rigid Cracking greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.
2. Concrete Pavement Rehabilitation B involves pavement grinding, **moderate** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking between 2 and 5%.
3. Concrete Pavement Rehabilitation C involves pavement grinding, **minor** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking 2% or less.
4. The schedule for this strategy is based on pavement that has previously been cracked, seated and overlaid. It should not be used as an alternative on rigid JPCP pavements with cracking or faulting near or above the threshold for roadway rehabilitation.

TABLE R-2 (b)
High Mountain and High Desert Climate Regions
RIGID AND COMPOSITE PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Pavement Type	Pvmt Design Life	Maint. Service Level	Year	0	5	10	15	20	25	30	35	40	45	50	55
CAPM															
Slab Replacement (CPR[3])	10	1,2,3	Year of Action	0		10	15	20							
			Activity Description	CAPM (CPR C[3])		CAPM (CPR B[2])	CAPM (CPR A[1])	Roadway Rehab[4]	Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence						
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 2,098		5 / 4135	5 / 4,135								
Composite	5	1,2,3	Year of Action	0											
			Activity Description	**CAPM (Flex Overlay)**	The maintenance and rehabilitation schedules depend on the previous history and condition of the existing pavement. To determine the appropriate M&R schedule to use, first determine the initial pavement type and the original rehabilitation completed. Next, determined any other rehabilitations and/or CAPM projects completed after the initial rehabilitation. Ignore projects that only removed and replaced RHMA-G or RHMA-O. Finally, find a schedule on the rehabilitation M&R table that best describes the original rehabilitation completed and that sequence. However, from the pavement history, take into consideration the activities already completed in that sequence.										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 /											
Composite	5	1,2,3	Year of Action	0											
			Activity Description	**CAPM (FO + JPCP SR)**	EXAMPLE: You are doing a Flexible Overlay and JPCP Slab Replacement on a previously cracked, seated, and overlaid project (doesn't matter whether it was 10 or 20 year). Previous work included a remove and replace RHMA-O 7 years after the crack, seat, and flexible overlay (CSFOL) rehabilitation, and a 0.10' HMA overlay at 18 years after the CSFOL project. From this information it can be determined that the initial pavement type was rigid and the original rehabilitation completed was a CSFOL. If the RHMA-O project at year 7 is ignored, it can be determined that the best fit for this sequence is the 20-year CSFOL. The 0.10' HMA overlay at 18 years after the completion of the CSFOL is the first CAPM under this sequence and the future activities will include a CAPM (FO + JPCP SR) at Year 23 and a 20-year rehab at Year 28. Remember to follow the sequence until you fulfill the analysis period.										
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life												
Rigid - Jointed Plain Concrete Pavement (JPCP)	5	1,2,3	Year of Action	0	5										
			Activity Description	**CAPM (CPR A[1])**	Roadway Rehab	Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence									
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 / 5,100											
Rigid - Jointed Plain Concrete Pavement (JPCP)	10	1,2,3	Year of Action	0		10	15								
			Activity Description	**CAPM (CPR B[2])**		CAPM (CPR A[1])	Roadway Rehab	Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence							
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	10 / 1,500		5 / 3,100									
Rigid - Jointed Plain Concrete Pavement (JPCP)	5	1,2,3	Year of Action	0	5		15	20							
			Activity Description	**CAPM (CPR C[3])**	CAPM (CPR B[2])		CAPM (CPR A[1])	Roadway Rehab	Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence						
			Activity Service Life (years) / Annual Maint. Cost ($/lane-mile) over Activity Service Life	5 / 3,000	5 / 1,500		5 / 4,393								

CPR = Concrete Pavement Rehabilitation, CSFOL = Crack, Seat, and Flexible Overlay, FO = Flexible Overlay, MSRO = Mill, Slab Replacement & Overlay, SR = Slab Replacement

Notes:

1. Concrete Pavement Rehabilitation A involves pavement grinding, **significant** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs that were replaced or exhibit third stage Rigid Cracking greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.
2. Concrete Pavement Rehabilitation B involves pavement grinding, **moderate** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking between 2 and 5%.
3. Concrete Pavement Rehabilitation C involves pavement grinding, **minor** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking 2% or less.
4. The schedule for this strategy is based on pavement that has previously been cracked, seated and overlaid. It should not be used as an alternative on rigid JPCP pavements with cracking or faulting near or above the threshold for roadway rehabilitation.

TABLE R-2 (c)
High Mountain and High Desert Climate Regions
RIGID AND COMPOSITE PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Pavement Type	Pvmt Design Life	Maint. Service Level	Year	0	5	10	15	20	25	30	35	40	45	50	55
Rehabilitation (a)															
Flexible/ Composite	20	1,2,3	Year of Action	0				18	23	28				46	51
			Activity Description	**20-yr Rehab (CSFOL)**				CAPM (Flex Overlay)	CAPM (FO+ JPCP SR)	20-yr Rehab (MSRO)				CAPM (FO+ JPCP SR)	CAPM (FO+ JPCP SR)
			Activity Service Life (years)	18				5	5	18				5	7
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	6,300				1,100	1,100	6,300				1,100	900
	20	1,2,3	Year of Action	0				18	23	30					
			Activity Description	**20-yr Rehab (MSRO)**				CAPM (FO + JPCP SR)	CAPM (FO + JPCP SR)	Lane Replace	Select a lane replace option listed under the rigid and composite pavement M&R table and follow the strategy sequence				
			Activity Service Life (years)	18				5	7						
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	6,300				1,100	900						
	20 & 40	1,2,3	Year of Action	0											
			Activity Description	**Lane Replace**	Follow the strategies for new construction/reconstruction in the applicable flexible pavement tables for the appropriate climate region										
			Activity Service Life (years)												
			Annual Maint. Cost ($/lane-mile) over Activity Service Life												
	20	1,2,3	Year of Action	0						30		40	45		
			Activity Description	**20-yr Rehab (Lane Replace)**						CAPM (FO+ JPCP SR)		CAPM (FO+ JPCP SR)	Lane Replace	Select a lane replace option listed under the rigid and composite pavement M&R table and follow the strategy sequence	
			Activity Service Life (years)	30						10		5			
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	7,300						5,900		1,100			
	40	1,2,3	Year of Action	0										50	
			Activity Description	**40-yr Rehab (Lane Replace)**										CAPM (FO+ JPCP SR)	
			Activity Service Life (years)	50										5	
			Annual Maint. Cost ($/lane-mile) over Activity Service Life	8,400										1,100	

CPR = Concrete Pavement Rehabilitation, CSFOL = Crack, Seat, and Flexible Overlay, FO = Flexible Overlay, MSRO = Mill, Slab Replacement & Overlay, SR = Slab Replacement

Notes:

1. Concrete Pavement Rehabilitation A involves pavement grinding, **significant** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs that were replaced or exhibit third stage Rigid Cracking greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.
2. Concrete Pavement Rehabilitation B involves pavement grinding, **moderate** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking between 2 and 5%.
3. Concrete Pavement Rehabilitation C involves pavement grinding, **minor** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking 2% or less.
4. The schedule for this strategy is based on pavement that has previously been cracked, seated and overlaid. It should not be used as an alternative on rigid JPCP pavements with cracking or faulting near or above the threshold for roadway rehabilitation.

TABLE R-2 (d)
High Mountain and High Desert Climate Regions
RIGID AND COMPOSITE PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Pavement Type	Pvmt Design Life	Maint. Service Level	Year		0		5	10	15	20	25		30		35	40		45		50		55
Rehabilitation (b)																						
Rigid - Jointed Plain Concrete Pavement (JPCP)	20	1,2,3	Year of Action		0						25		30			40		45		Select a rehabilitation option listed under the rigid and composite pavement M&R table and follow the strategy sequence		
			Activity Description		**20-yr Rehab (Lane Replace)**						CAPM (CPR C[3])		CAPM (CPR B[2])			CAPM (CPR A[1])		Roadway Rehab				
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	25	3,100					5	3,000	10	1,500		5	5,100					
	40	1,2,3	Year of Action		0													45		50		
			Activity Description		**40-yr Rehab (Lane Replace)**													CAPM (CPR C[3])		CAPM (CPR B[2])		
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	45	3,200												5	3,000	10	1,500	

CPR = Concrete Pavement Rehabilitation, CSFOL = Crack, Seat, and Flexible Overlay, FO = Flexible Overlay, MSRO = Mill, Slab Replacement & Overlay, SR = Slab Replacement

Notes:

1. Concrete Pavement Rehabilitation A involves pavement grinding, **significant** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs that were replaced or exhibit third stage Rigid Cracking greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.
2. Concrete Pavement Rehabilitation B involves pavement grinding, **moderate** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking between 2 and 5%.
3. Concrete Pavement Rehabilitation C involves pavement grinding, **minor** slab replacement, spall repair, & joint seal repair. It is for **JPCP** projects with a total number of slabs in the lane that were replaced or exhibit third stage Rigid Cracking 2% or less.
4. The schedule for this strategy is based on pavement that has previously been cracked, seated and overlaid. It should not be used as an alternative on rigid JPCP pavements with cracking or faulting near or above the threshold for roadway rehabilitation.

APPENDIX 5: TRAFFIC INPUTS ESTIMATION

A. Free Flow Capacity

The alternate procedure for estimating the "Free Flow Capacity (vphpl)" is as follows: (Assume standard lane and shoulder widths)

Select a passenger car equivalent factor, E (passenger cars/heavy vehicle), corresponding to the project terrain from Table 15:

Table 15. Passenger Car Equivalent Factors

	Type of Terrain		
	Level	**Rolling**	**Mountainous**
E	1.5	2.5	4.5

Use Equation A5-1 to convert "Free Flow Capacity" in terms of pcphpl to vphpl (vehicles per hour per lane):

$$FC = \frac{F \times 100}{[(100 + P \times (E-1)]} \qquad \text{(Equation A5-1)}$$

Where

FC = Free Flow Capacity (vphpl)

F = roadway capacity (passenger car per hour per lane)

= 1,700 pcphpl for two-lane highways

= 2,300 pcphpl for multi-lane highways

P = percentage of heavy vehicles (i.e., "Total Trucks %" at the project location)

E = passenger car equivalent (passenger cars/heavy vehicle)

B. Queue Dissipation Capacity

The procedure for estimating the “Queue Dissipation Capacity (vphpl)” is as follows: (Assume standard lane and shoulder widths)

Select a passenger car equivalent factor, E (passenger cars/heavy vehicle), corresponding to the project terrain from Table 15;

Use Equation A5-2 to convert “Queue Dissipation Capacity” in terms of pcphpl to vphpl (vehicles per hour per lane):

$$QC = \frac{Q \times 100}{[(100 + P \times (E - 1)]} \qquad \text{(Equation A5-2)}$$

Where

QC = Queue Dissipation Capacity (vphpl)

Q = base capacity (passenger cars per hour per lane)

= 1,800 pcphpl for both single-lane and multi-lane highways

P = percentage of heavy vehicles (i.e., “Total Trucks %” at the project location)

E = passenger car equivalent (passenger cars/heavy vehicle)

C. Maximum AADT (total for both directions)

The procedure for estimating the "Maximum AADT (total for both directions)" is as follows:

Select a passenger car equivalent factor, E (passenger cars/heavy vehicle), corresponding to the project terrain from Table 15;

Use Equation A5-3 to calculate "Maximum AADT (total for both directions)":

$$AADT_{\max} = \frac{M \times N \times 100}{[(100 + P \times (E - 1)]} \qquad \text{(Equation A5-3)}$$

Where

$\mathbf{AADT_{max}}$ = Maximum AADT (total for both directions)

M = 43,000 for two-lane highways or 57,000 for multi-lane highways

N = number of lanes (total for both directions)

P = percentage of heavy vehicles (i.e., "Total Trucks %" at the project location)

E = passenger car equivalent (passenger cars/heavy vehicle)

D. Work Zone Capacity

The procedure for estimating the "Work Zone Capacity (vphpl)" is as follows:
(Assume standard lane and shoulder widths)

Select a passenger car equivalent factor, E (passenger cars/heavy vehicle), corresponding to the project terrain from Table 15.

Use Equation A5-4 to convert "Work Zone Capacity" in terms of pcphpl to vphpl (vehicles per hour per lane):

$$WC = \frac{W \times 100}{[(100 + P \times (E - 1)]} \qquad \text{(Equation A5-4)}$$

Where

WC = Work Zone Capacity (vphpl)

W = base work zone capacity (passenger cars per hour per lane)

W = 1,100 pcphpl for two-lane highways

= 1,600 pcphpl for multi-lane highways

P = percentage of heavy vehicles (i.e., "Total Trucks %" at the project location)

E = passenger car equivalent (passenger cars/heavy vehicle)

E. Maximum Queue Length Estimation

The maximum number of queued vehicles during the time the work zone is in effect is estimated by using the traffic demand-capacity model, as shown in Figure A5-1. When demand exceeds capacity, the queue starts to build up. The maximum number of queued vehicles is measured where the difference between the demand curve and the capacity curve is the greatest. Then the maximum queue length can be obtained by multiplying the maximum number of queued vehicles by the average vehicle length (i.e., 40 feet).

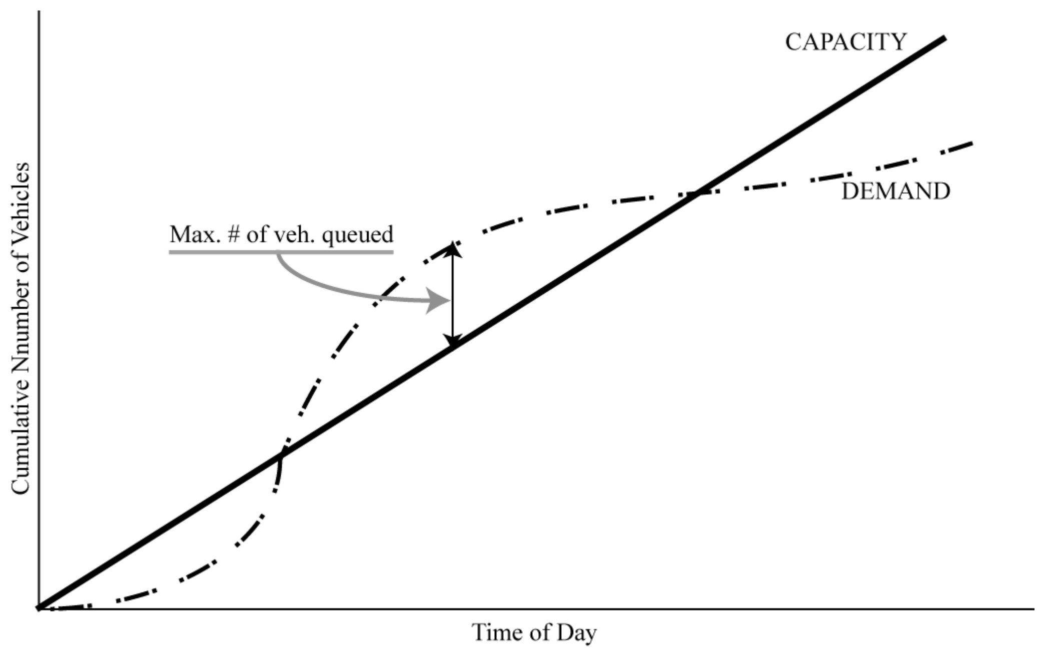

Figure A5-1: Traffic Demand-Capacity Model

Example:

Maximum Queue Length Estimation

During construction on a three-lane urban freeway section, one lane will be closed and two lanes will be open. The work zone capacity is assumed to be 1,600 passenger cars per hour per lane (pcphpl). The hourly traffic demands, expressed in vehicles per hour (vph), are assumed to be those shown in the second column in Table 16. Ten percent of the traffic volume is assumed to be occupied by single-unit and combination trucks. The procedure for estimating the maximum queue length is:

The hourly passenger car capacity of one lane (1,600 pcphpl) of the work zone is converted to the hourly vehicular capacity of one lane [1,524 vphpl (vehicles per hour per lane)] of the work zone using Equation A5-4.

Hour	Volume (vph)	Capacity (pcphpl)	Capacity (vphpl)	No. of lanes open	Capacity (vph)	Cumulative Queued veh.
1	340	1,600	1,524	2	3,048	0
2	350	1,600	1,524	2	3,048	0
3	350	1,600	1,524	2	3,048	0
4	400	1,600	1,524	2	3,048	0
5	800	1,600	1,524	2	3,048	0
6	1,200	1,600	1,524	2	3,048	0
7	3,000	1,600	1,524	2	3,048	0
8	3,400	1,600	1,524	2	3,048	352
9	3,600	1,600	1,524	2	3,048	904
10	3,000	1,600	1,524	2	3,048	856
11	1,800	1,600	1,524	2	3,048	0
12	1,300	1,600	1,524	2	3,048	0
13	1,200	1,600	1,524	2	3,048	0
14	1,000	1,600	1,524	2	3,048	0
15	1,200	1,600	1,524	2	3,048	0
16	1,900	1,600	1,524	2	3,048	0
17	3,400	1,600	1,524	2	3,048	352
18	3,650	1,600	1,524	2	3,048	954
19	2,400	1,600	1,524	2	3,048	306
20	1,000	1,600	1,524	2	3,048	0
21	800	1,600	1,524	2	3,048	0
22	760	1,600	1,524	2	3,048	0
23	300	1,600	1,524	2	3,048	0
24	300	1,600	1,524	2	3,048	0
					Max. queued veh.	954
	Max. queued veh. on 3 lanes, at upstream of work zone					318
					Average vehicle length	40 ft
					Max. queue length	12,720 ft
						2.41 mi

Table 16. Maximum Queue Length Estimation

As shown in Table 16, the queue starts at slightly after 7 AM when the traffic demand exceeds the work zone capacity (3,048 vph) and starts dissipating after 10 AM when the sum of the hourly demand becomes less than the work zone capacity. The queue is completely dissipated by 11 AM, and starts again at about 5 PM when the traffic demand exceeds the work zone capacity (3,048 vph).

The maximum number of queued vehicles is 954 at 6 PM when the cumulative number of the queued vehicles is the greatest. The maximum number of queued vehicles per lane upstream of the work zone is 318 (954 vehicles divided by 3 lanes). Thus, the maximum queue length from the work zone operation is estimated at 2.41 miles (318 vehicles multiplied by 40 ft average vehicle length).

APPENDIX 6: ALTERNATE PROCEDURE FOR CALCULATING CONSTRUCTION YEAR AADT

The following steps describe how to get a construction year AADT:

1) Go to the Division of Traffic Operations website (http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/index.htm). Download the most current year AADT data available (such as "2008 AADT" in Excel file format). Find "Back AADT" and "Ahead AADT" numbers at the project location and average those two numbers to get the total AADT for both directions in the most current year.

2) Contact the Division of Transportation System Information for the "Annual Growth Rate of Traffic" or AADT values (in the most current and future years) expected at the project location. An approximate "Annual Growth Rate of Traffic" can be estimated with the available AADT values using Equation A6-1 below:

$$A = [(\frac{FT}{MT})^{(\frac{1}{FY-MY})} - 1] \times 100 \qquad \text{(Equation A6-1)}$$

Where

A = Annual Growth Rate of Traffic (%)

FT = Future Year AADT (total for both directions)

MT = Most Current Year AADT (total for both directions)

FY = Future Year in which AADT is available

MY = Most Current Year in which AADT is available.

Example:

Given:

Future Year AADT (total for both directions) = 18,000 (year 2025)

Most Current Year AADT (total for both directions) = 9,800 (year 2005)

The Annual Growth Rate of Traffic is

$$[(\frac{18,000}{9,800})^{(\frac{1}{2025-2005})} - 1] \times 100 = 3.09\%$$

Use the following equation to calculate the AADT total for both directions in the initial construction year or the beginning year of the analysis period:

$$I\_AADT = MT \times (1 + \frac{A}{100})^{(IY-MY)} \qquad \text{(Equation A6-2)}$$

Where

I_AADT = Initial Construction Year AADT (total for both directions)

MT = Most Current Year AADT (total for both directions)

A = Annual Growth Rate of Traffic (%)

IY = Initial Construction Year (same as the first year of the analysis period)

MY = Most Current Year in which AADT is available.

Example:

Using the most current year AADT (2005) = 9,800

Determine AADT for 2007 as the Initial Construction year

The Initial Construction year AADT is:

$$(9,800)x(1 + \frac{3.09}{100})^{(2007-2005)} = 10,415$$

APPENDIX 7: WEEKEND TRAFFIC HOURLY DISTRIBUTION

Hour	AADT Rural (%)	Inbound Rural (%)	Outbound Rural (%)	AADT Urban (%)	Inbound Urban (%)	Outbound Urban (%)
0 - 1	1.91	47.6	52.4	1.8	47.7	52.3
1 - 2	1.61	49.5	50.5	1.3	47.8	52.2
2 - 3	1.32	49.0	51.0	0.9	46.5	53.5
3 - 4	1.52	54.9	45.1	0.8	52.2	47.8
4 - 5	1.64	54.9	45.1	0.9	56.3	43.7
5 - 6	2.13	53.0	47.0	1.5	55.5	44.5
6 - 7	2.86	50.8	49.2	2.4	53.2	46.8
7 - 8	3.58	50.4	49.6	3.4	51.6	48.4
8 - 9	4.38	50.0	50.0	4.6	50.9	49.1
9 - 10	5.22	50.7	49.3	5.5	50.2	49.8
10 - 11	5.96	51.3	48.7	6.2	49.8	50.2
11 - 12	6.46	50.6	49.4	6.7	49.1	50.9
12 - 13	6.58	50.9	49.1	7.0	48.7	51.3
13 - 14	6.58	51.3	48.7	7.0	48.5	51.5
14 - 15	6.66	52.4	47.6	7.1	47.9	52.1
15 - 16	6.89	53.1	46.9	7.0	48.1	51.9
16 - 17	6.73	52.9	47.1	6.7	47.9	52.1
17 - 18	6.21	52.6	47.4	6.3	48.4	51.6
18 - 19	5.54	51.5	48.5	5.7	48.4	51.6
19 - 20	4.77	50.7	49.3	5.0	48.9	51.1
20 - 21	4.02	51.4	48.6	4.2	48.8	51.2
21 - 22	3.28	51.4	48.6	3.5	49.5	50.5
22 - 23	2.60	50.7	49.3	2.7	49.6	50.4
23 - 24	1.54	48.6	51.4	1.6	49.8	50.2
	100.0			100.0		

APPENDIX 8: PROCEDURES FOR ESTIMATING RAMP ALTERNATIVES

Procedures for Analyzing Ramps

Since the introduction of the Life-Cycle Cost Analysis Procedures Manual in 2007, there have been a number of questions raised regarding how to analyze ramps, particularly when ramps are the only pavement element of a project. The following procedures are provided to clarify ramp analysis and aid designers in analyzing ramps as well as provide allowances to simplify the process. These procedures should be considered as the minimum allowable for LCCA for state highways. Districts always have the discretion to analyze or require more locations and options than what these procedures suggest.

Ramps as Part of a Larger Project

- Omit Ramp analysis:

  When ramps are included as part of a larger project to widen, rehabilitate, or build a state highway, the district may omit the analysis of the ramps in the LCCA. When omitting, it is assumed that the results for the ramps will be the same as the result for the mainline. It is also assumed that the pavement design criteria and life use for the mainline will be used for the ramps.

- Include Ramp analysis:

  See below the process used for Ramps as Part of a Separate Project.

Ramps as Part of a Separate Project

For projects that propose pavement work only on ramps (such as interchange modification projects), it is not necessary to perform an LCCA for each individual ramp. Instead, at a minimum, the designer should select the on and/or off ramps that best represents all the ramps for the project and add the results. These are usually the ramps with the highest traffic volume.

If the project proposes auxiliary lanes, a separate analysis is not required provided the following conditions are met.

- Auxiliary lanes are short (typically around 1000-feet in length or less) and serve only to aid with traffic handling for the ramp and do not extend to the next interchange
- There are no plans to extend the auxiliary lanes to the next interchange or convert the lane into a through traffic lane within the life span of the pavement.

The District is responsible for making the determination as to whether the above conditions have been met.

Which Part of the Ramp to Analyze for Agency Construction Cost

Ramps have three basic segments, the gore, middle, and the termini at the intersection with the local road. (Note: not all ramps have an end treatment.)

When analyzing the middle segment, the designer should take into account the constructability of the entire ramp when estimating costs and making final decisions. For example, when the gore area is concrete and the ramp termini is also concrete, it may be more cost effective in initial costs to pave the entire ramp with concrete because of the lower labor and mobilization costs.

Estimating User Delay

When estimating the user delay for ramps, the following assumptions can be made unless District Traffic Operations provides specific data for the ramp.

For the Project-Level and Traffic Data Inputs, enter the following:

- AADT Construction Year (total for both directions)
  On ramp: add traffic volume of local road to the ramp volume
  Off ramp: add traffic volume of mainline to the ramp volume

- Speed Limit Under Normal Operating Conditions
  On ramp: use posted speed limit of the road, which is feeding the on ramp (mph)
  Off ramp: use posted speed limit of the mainline in that direction (mph)

- Lanes Open in Each Direction Under Normal Conditions
  On ramp: use number of through lanes on the road, which is feeding the on ramp + 1 lane (to represent the ramp)
  Off ramp: use number of through lanes on the mainline in that direction + 1 lane (to represent the ramp)

- Maximum AADT (total for both directions)
  On ramp: calculate the value by using the total number of through lanes on the road, which is feeding the on ramp
  Off ramp: calculate the value by using the total number of through lanes on the mainline

- All other values are entered as per the manual based on data and information of the mainline.

For the Alternative Inputs, enter the following:

- Agency Construction Cost, Activity Service Life, and Agency Maintenance Cost:
  Based on the information of the ramp you are analyzing
- Work Zone Length:
  Enter a length of no less than 1 mile.
- Number of Lanes Open in Each Direction During Work Zone:
  Enter the number of through lanes on the road/mainline.
- Work Zone Duration:
  Based on the information of the ramp you are analyzing and the construction window prescribed under Work Zone Hours in Section 3.3.8.
- Work Zone Speed Limit:
  Enter the Posted Speed Limit for the road/mainline (mph) – 5 mph
  or the speed determined by District Traffic Operations
- Work Zone Hours:
  Enter the time frame the ramp is closed from the Traffic Management Plan. If no traffic closure data is available, enter 0 to 6 as the First period of closure and enter 21 to 24 as the Second period of closure.

APPENDIX 9: LIST OF TABLES

Table 1. Typical Alternatives for Various Types of Projects with Pavement [1]

Pvmt Project Type	Document	Conditions	Alternative 1	Alternative 2	Alternative 3	Other Alternatives that could be considered		
	PID	**20-yr Traffic Index (TI_{20})**						
		$TI_{20} > 15$	20-yr Rigid (JPCP)	40-yr Rigid (JPCP)	40-yr Rigid (CRCP)	20-yr Flex[2]	20-yr Composite[3]	40-yr Composite[3]
		$10 < TI_{20} \leq 15$	20-yr Flex[4]	40-yr Rigid (JPCP)	40-yr Flex[4]	40-yr Rigid (CRCP)	20-yr Composite[3]	40-yr Composite[3]
		$TI_{20} \leq 10$	20-yr Flex[4]	40-yr Rigid (JPCP)	40-yr Flex[4]	20-yr Composite[3]	40-yr Composite[3]	
	PR (PA&ED)	**PID Preferred Pvmt Type & Design Life**						
New/ Reconstruction		Flexible (20-yr design)	Flex (HMA)	Flex (RHMA)	Rigid (JPCP)	Flex (HMA w/ OGFC)	Flex (RHMA-G w/ RHMA-O)	Flex (HMA w/ RHMA)
		Flexible (40-yr design)	Flex (HMA w/ OGFC)	Flex (RHMA-G w/ RHMA-O)	Rigid (JPCP)	Flex (HMA w/ RHMA)	Rigid (CRCP)	
		Rigid (20-yr design)	Rigid (JPCP)	Flex (RHMA)	Flex (HMA)			
		Rigid (40-yr design)	Rigid (JPCP)	Rigid (CRCP)[5]	Flex (RHMA w/ RHMA-O)	Composite[3]	Flex (HMA w/ RHMA)	
		Composite (20-yr design)	Composite (HMA)	Composite (RHMA)	Flex (HMA)	Flex (RHMA)	Rigid (JPCP)	Flex (HMA w/ RHMA)
		Composite (40-yr design)	Composite (HMA)	Composite (RHMA)	Rigid (JPCP)	Rigid (CRCP)	Flex (RHMA-G w/ RHMA-O)	Flex (HMA w/ RHMA)
	PID	**Existing Road Pvmt Surface**						
		Flexible	RSL Flex	20-yr Flex	40-yr Flex	40-yr Composite[3]	20-yr Composite[3]	
		Rigid	RSL Rigid	RSL Flex	40-yr Rigid			
		Composite[6]	RSL Composite	20-yr Flex	40-yr Composite	20-yr Composite	RSL Flex	
	PR (PA&ED)	**PID Preferred Pvmt Type & Design Life**						
Widening		Flexible (≤ 20-yr design)	HMA	HMA w/ RHMA	RHMA	HMA w/ OGFC	RHMA-G w/ RHMA-O	
		Flexible (> 20-yr design)	HMA w/ RHMA	RHMA-G w/ RHMA-O	HMA w/ OGFC			
		Rigid (≤ 20-yr design)	Rigid	Flex (RHMA)	Flex (HMA)			
		Rigid (> 20-yr design)	Rigid			Flex (RHMA-G w/ RHMA-O)	Flex (HMA w/ OGFC)	
		Composite[6] (≤ 20-yr design)	Composite (HMA)	Composite (RHMA)	Flex (RHMA)	Flex (HMA)	Rigid	
		Composite[6] (> 20-yr design)	Composite (RHMA)	Flex (RHMA-G w/ RHMA-O)	Flex (HMA w/ OGFC)	Composite (HMA)		
	PR	**Existing Road Pvmt Surface**						
		Flexible	HMA	RHMA	HMA w/ RHMA	HMA w/ OGFC	RHMA-G w/ RHMA-O	
CAPM		Rigid (< 5% slab replacement)	Grinding (Rigid Strategy)	Thin RHMA Overlay				
		Rigid (≥ 5% slab replacement)	Grind & Slab Replacements	Lane Replacement (Rehab Strategy)				
		Composite[6]	Use Flexible CAPM Alternatives					
	PSSR	**Existing Road Pvmt Surface**						
		Flexible	HMA	RHMA		HMA w/ OGFC	RHMA-G w/ RHMA-O	
Roadway Rehabilitation		Flexible w/ OGFC or RHMA-O	HMA w/ OGFC	RHMA-G w/ RHMA-O				
		Rigid	10-yr Crack, Seat & Flex Overlay	20-yr Crack, Seat & Flex Overlay	40-yr Lane Replacement	20-yr Lane Replacement	40-yr Crack, Seat & Flex Overlay[2]	
		Composite[6]	10-yr Overlay	20-yr Overlay	40-yr Lane Replacement	20-yr Lane Replacement		

Flex = Flexible Rehab = Rehabilitation Pvmt = Pavement yr = year

Notes:

(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.

(2) Highway Design Manual (HDM) currently does not provide a methodology for this design. Consult the Office of Pavement Engineering for special design options.

(3) Composite Pvmt may be thin Flex surface (≤ 0.25') over JPCP or CRCP. Choose the same rigid Pvmt type that is being analyzed for one of the other alternatives. Assume RHMA for flexible surface unless it is desired to analyze both RHMA and HMA alternatives or RHMA is not viable (see HDM 631.3)

(4) Assume RHMA unless there are specific reasons RHMA cannot be used. Document these reasons in Project Initiation Documents. If sufficient information is available, can opt to analyze HMA vs. RHMA in addition to rigid pavement alternatives.

(5) Consider only for $TI_{20} \geq 12$.

(6) Includes previously built crack, seat, and flexible overlay projects.

Table 2. LCCA Analysis Periods

Alternative Design Life	CAPM	10-Yr	15 or 20-Yr	25 to 40-Yr
CAPM	20 years	20 years	20 years	
10-Yr	20 years	20 years	35 years	55 years
15 or 20-Yr	20 years	35 years	35 years	55 years
25 to 40-Yr		55 years	55 years	55 years

Table 3. Agency Project Support Cost Multipliers*

Type of Project		Range of Project ($)	Multiplier w/ Right-of-Way	Multiplier w/o Right-of-Way
New Construction/ Reconstruction	Small	750,000 - 5,000,000	0.47	0.39
	Medium	5,000,001 - 20,000,000	0.31	0.29
	Large	20,000,001 - 35,000,000	0.25	0.23
	Very Large	35,000,001 - Up	0.24	0.20
Widening	Small	750,000 - 2,500,000	0.56	0.52
	Medium	2,500,001 - 5,000,000	0.39	0.35
	Large	5,000,001 - 15,000,000	0.28	0.26
	Very Large	15,000,001 - Up	0.25	0.24
CAPM	Small	750,000 - 2,000,000	0.19	0.19
	Medium	2,000,001 - 5,000,000	0.18	0.15
	Large	5,000,001 - Up	0.16	0.13
Roadway Rehabilitation	Small	750,000 - 2,000,000	0.35	0.31
	Medium	2,000,001 - 5,000,000	0.28	0.26
	Large	5,000,001 - Up	0.20	0.19

* Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in table.

Table 4. Estimated Construction Costs of Typical M&R Strategies for Flexible Pavements (1)

Final Surface Type	Pavement Design Life (years)	Future M&R Activity Description	$/Lane-Mile(2)
CAPM			
HMA	5+	Overlay	**99,000**
	5+	Mill & Overlay	**118,000**
HMA w/ OGFC	5+	Overlay	**146,000**
	5+	Mill & Overlay	**165,000**
HMA w/ RHMA	5+	Overlay	**161,000**
	5+	Mill & Overlay	**180,000**
RHMA	5+	Overlay	**100,000**
	5+	Mill & Overlay	**119,000**
RHMA w/ RHMA-O	5+	Overlay	**147,000**
	5+	Mill & Overlay	**162,000**
Rehabilitation			
HMA	10	Overlay	**299,000**
	20		**332,000**
	10	Mill & Overlay	**318,000**
	20		**351,000**
HMA w/ OGFC	10	Overlay	**346,000**
	20		**379,000**
	10	Mill & Overlay	**365,000**
	20		**398,000**
HMA w/ RHMA	10	Overlay	**361,000**
	20		**394,000**
	10	Mill & Overlay	**380,000**
	20		**413,000**
RHMA	10	Overlay	**327,000**
	20		**363,000**
	10	Mill & Overlay	**346,000**
	20		**379,000**
RHMA w/ RHMA-O	10	Overlay	**389,000**
	20		**422,000**
	10	Mill & Overlay	**408,000**
	20		**441,000**
Lane Replacement	**See Table 5b for options**		

Notes:
(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.
(2) Lane-mile construction costs excluding project support costs

Table 5a. Estimated Construction Costs of Typical M&R Strategies for Rigid & Composite Pavements (1)

Final Pavement Type	Pavement Design Life (years)	Future M&R Activity Description	$/Lane-Mile(5)
CAPM			
Flexible / Composite	5+	Flexible Overlay	81,000
		Flexible Overlay w/ JPCP Slab Replacements (**FO + JPCP SR**, RSC 12-Hour Curing Time)	84,000
		Flexible Overlay w/ JPCP Slab Replacements (**FO + JPCP SR**, RSC 4-Hour Curing Time)	91,000
Rigid - Jointed Plain Concrete Pavement (JPCP)	5+	Concrete Pavement Rehab A(2) (with RSC of 12-Hour Curing Time)	123,000
		Concrete Pavement Rehab A(2) (with RSC of 4-Hour Curing Time)	148,000
	5+	Concrete Pavement Rehab B(3) (with RSC of 12-Hour Curing Time)	88,000
		Concrete Pavement Rehab B(3) (with RSC of 4-Hour Curing Time)	106,000
	5 +/-	Concrete Pavement Rehab C(4) (with RSC of 12-Hour Curing Time)	82,000
		Concrete Pavement Rehab C(4) (with RSC of 4-Hour Curing Time)	89,000
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	5+	Punchout Repairs A(7) (with RSC of 12-Hour Curing Time)	163,000
		Punchout Repairs A(7) (with RSC of 4-Hour Curing Time)	175,000
	5+	Punchout Repairs B(8) (with RSC of 12-Hour Curing Time)	136,000
		Punchout Repairs B(8) (with RSC of 4-Hour Curing Time)	147,000
	5 +/-	Punchout Repairs C(9) (with RSC of 12-Hour Curing Time)	20,000
		Punchout Repairs C(9) (with RSC of 4-Hour Curing Time)	25,000

Notes:

(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.

(2) Concrete Pavement Rehab A involves pavement grinding, significant slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is greater than or equal to 5% and less than or equal to 7%. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(3) Concrete Pavement Rehab B involves pavement grinding, moderate slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2 and 5%.

(4) Concrete Pavement Rehab C involves pavement grinding, minor slab replacement, spall repair, & joint seal repair. It is for projects with a total number of slabs in the lane that exhibit third state Rigid Cracking or were previously replaced is between 2% or less. For greater than 7%, the project should be scoped and analyzed as a roadway rehabilitation project.

(5) Lane-mile construction costs excluding project support costs.

(6) Costs for terminal joint at $9,000 per lane should be applied in addition to lane replacement cost. Lane replacement costs are per lane-mile and terminal joint cost are per lane.

(7) Punchout Repair A involves **significant** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced Concrete pavements that had previous punchout repairs and a flexible overlay.

(8) Punchout Repair B involves **moderate** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced Concrete pavements where the total number of current and previous punchout repairs exceed 4 per mile.

(9) Punchout Repair C involves **minor** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced Concrete pavements where the total number of current and previous punchout repairs do not exceed 4 per mile.

Table 5b. Estimated Construction Costs of Typical M&R Strategies for Rigid & Composite Pavements (1)

Final Pavement Type	Pavement Design Life (years)	Future M&R Activity Description	$/Lane-Mile(5)
Rehabilitation			
Flexible / Composite	10	Flexible Overlay w/ Slab Replacements (**FO+JPCP SR**, **RSC of 12-Hour Curing Time**)	215,000
		Flexible Overlay w/ Slab Replacements (**FO+JPCP SR**, **RSC of 4-Hour Curing Time**)	233,000
	10	Mill, Slab Replacement & Overlay (**MSRO, RSC of 12-Hour Curing Time**)	234,000
		Mill, Slab Replacement & Overlay (**MSRO, RSC of 4-Hour Curing Time**)	252,000
	20	Mill, Slab Replacement & Overlay (**MSRO, RSC of 12-Hour Curing Time**)	260,000
		Mill, Slab Replacement & Overlay (**MSRO, RSC of 4-Hour Curing Time**)	280,000
	10	Crack, Seat, & Flexible Overlay **(CSFOL)**	251,000
	20		279,000
	20	Lane Replacement with Flexible	941,000
	40		1,255,000
	20	Lane Replacement with composite (with RSC of 12-Hour Curing Time)	2,011,000
	40		2,349,000
	20	Lane Replacement with composite (with RSC of 4-Hour Curing Time)	2,482,000
	40		2,821,000
Rigid - Jointed Plain Concrete Pavement (JPCP)	20	Lane Replacement (with RSC of 12-Hour Curing Time)	1,493,000
	40		1,752,000
	20	Lane Replacement (with RSC of 4-Hour Curing Time)	1,854,000
	40		2,113,000
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	20	Lane Replacement (with RSC of 12-Hour Curing Time)	1,951,000
	40		2,289,000
	20	Lane Replacement (with RSC of 4-Hour Curing Time)	2,422,000
	40		2,761,000

Notes:

See Table 5a.

Table 6. Traffic Input Values (1,2)

Type of Terrain	Level	Rolling	Mountainous	Level	Rolling	Mountainous
Free Flow Capacity (vphpl)	1,620	1,480	1,260	2,170	1,950	1,620
Queue Dissipation Capacity (vphpl)	1,710	1,570	1,330	1,700	1,530	1,270
Maximum AADT **Per** Lane	40,955	37,390	31,850	53,773	48,305	40,140
Work Zone Capacity (vphpl)(3)	1,050	960	820	1,510	1,360	1,130
Maximum Queue Length	7.0 miles if the estimated maximum queue length is longer than 7.0 miles			5.0 miles if the estimated maximum queue length is longer than 5.0 miles		

Notes:
(1) Derived from Highway Capacity Manual 2000.
(2) Refer to the calculation procedures included in Appendix 5, "Traffic Inputs Estimation".
(3) Assumed one lane to be open for traffic in single-lane highways and two or more lanes to be open for traffic in multi-lane highways.

Table 7. Transportation Component Consumer Price Indexes*

Year	US	LA CMSA(1)	SF CMSA(2)
1996	**143.0**	144.3	133.5
1997	**144.3**	145.2	133.6
1998	**141.6**	142.6	132.0
1999	**144.4**	146.8	135.8
2000	**153.3**	154.2	143.1
2001	**154.3**	155.3	143.7
2002	**152.9**	154.5	141.0
2003	**157.6**	160.3	145.0
2004	**163.1**	166.5	149.6
2005	**175.2**	176.2	157.3
2006	**178.0**	177.1	159.3
2007	**177.2**	171.6	156.2
2008 & beyond	**177.9**	167.3	154.1

Notes:
* Source: California Department of Finance, Economic Research Unit
http://www.dof.ca.gov/HTML/FS_DATA/LatestEconData/FS_Price.htm
(1) LA CMSA (Consolidated Metropolitan Statistical Area): includes counties of Los Angeles, Orange, Riverside, San Bernadino, & Ventura
(2) SF CMSA (Consolidated Metropolitan Statistical Area): includes counties of Alameda,

Table 8. Productivity Estimates of Typical Future Rehabilitation Strategies for Flexible Pavements [1,2]

Final Surface Type	Future M&R Alternative	Pavement Design Life (years)	Maintenance Service Level	Average Lane-mile Completed Per Closure[3]: Daily Closure (Weekday) 5 to 7-Hour Closure	Daily Closure (Weekday) 8 to 12-Hour Closure	Continuous Closure 16 hour/day Operation[4]	Continuous Closure 24 hour/day Operation[5]	Weekend Closure[6] (55-Hour)
CAPM								
HMA	Overlay	5+	1,2,3	0.63	1.50	2.67	4.83	15.13
	Mill & Overlay	5+	1,2,3	0.27	0.64	1.02	1.84	5.16
HMA w/ OGFC	Overlay	5+	1,2,3	0.42	0.92	1.74	3.17	9.92
	Mill & Overlay	5+	1,2,3	0.22	0.41	0.78	1.51	4.41
HMA w/ RHMA	Overlay	5+	1,2,3	0.42	0.92	1.74	3.17	9.92
	Mill & Overlay	5+	1,2,3	0.22	0.41	0.78	1.51	4.41
RHMA-G	Overlay	5+	1,2,3	0.85	1.99	3.55	6.42	20.12
	Mill & Overlay	5+	1,2,3	0.29	0.79	1.24	2.23	6.21
RHMA-G w/ RHMA-O	Overlay	5+	1,2,3	0.32	1.16	2.08	3.79	11.87
	Mill & Overlay	5+	1,2,3	0.24	0.59	0.98	1.77	5.16
Rehabilitation								
HMA	Overlay	10	1,2,3	0.28	0.70	1.41	2.72	8.57
		20	1,2,3	0.18	0.38	1.05	1.91	6.02
	Mill & Overlay	10	1,2,3	0.14	0.37	0.48	1.09	3.26
		20	1,2,3	0.06	0.26	0.25	0.75	2.19
HMA w/ OGFC	Overlay	10	1,2,3	0.23	0.44	1.03	2.08	6.58
		20	1,2,3	0.16	0.50	0.63	1.53	4.96
	Mill & Overlay	10	1,2,3	0.13	0.33	0.40	0.94	2.91
		20	1,2,3	0.06	0.24	0.40	0.60	2.03
HMA w/ RHMA	Overlay	10	1,2,3	0.23	0.44	1.03	2.08	6.58
		20	1,2,3	0.16	0.50	0.63	1.53	4.96
	Mill & Overlay	10	1,2,3	0.13	0.33	0.40	0.94	2.91
		20	1,2,3	0.06	0.24	0.40	0.60	2.03
RHMA-G	Overlay	10	1,2,3	0.63	1.50	2.67	4.83	15.13
		20	1,2,3	0.42	0.92	1.74	3.17	9.92
	Mill & Overlay	10	1,2,3	0.27	0.64	1.02	1.84	5.16
		20	1,2,3	0.18	0.31	0.65	1.30	3.77
RHMA-G w/ RHMA-O	Overlay	10	1,2,3	0.42	0.92	1.74	3.17	9.92
		20	1,2,3	0.32	0.64	1.26	2.34	7.39
	Mill & Overlay	10	1,2,3	0.22	0.41	0.78	1.51	4.41
		20	1,2,3	0.16	0.37	0.54	1.12	3.32

Notes:
UD - Under Development. See Office of Pavement Design for Assistance
(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.
(2) Refer to Appendix 3 for a expanded version of the table.
(3) Production rates in this table are based on representative assumptions that are applied consistently throughout the table.
These rates are only for calculating future user costs for the procedures in this manual and not for any other purpose.
More project specific user costs for some freeway situations can be obtained from the CA4PRS software.
(4) 24-hour continuous closure with 16 hours of operation per day
(5) 24-hour continuous closure with 24 hours of operation per day
(6) 55-hour extended closure over the weekend

Table 9. Productivity Estimates of Typical Future Rehabilitation for Rigid and Composite Pavements (1,2)

Final Surface Type	Future M&R Alternative		Pavement Design Life (years)	Maintenance Service Level	Average Lane-mile Completed Per Closure(3)				
					Daily Closure (Weekday)		Continuous Closure		Weekend Closure(6) (55-Hour)
					5 to 7-Hour Closure	10-Hour Closure	16 hour/day Operation(4)	24 hour/day Operation(5)	
CAPM									
Flexible / Composite	Flexible Overlay		5+	1,2,3	0.85	1.99	3.55	6.42	20.12
	Flexible Overlay w/ Slab Replacements **(FO + JPCP SR)**	4-hr RSC	5+	1,2,3	0.31	1.55	2.91		
		12-hr RSC					1.47	4.45	16.19
Rigid - Jointed Plain Concrete Pavement (JPCP)	Concrete Pavement Rehab A(3)	4-hr RSC	5+	1,2,3	0.14	2.00	4.57		
		12-hr RSC					0.71	4.14	23.71
	Concrete Pavement Rehab B(4)	4-hr RSC	5+	1,2,3	0.20	2.80	6.40		
		12-hr RSC					1.00	5.80	33.20
	Concrete Pavement Rehab C(5)	4-hr RSC	5+	1,2,3	0.50	7.00	16.00		
		12-hr RSC					2.50	14.50	83.00
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	Punchout Repairs A(7)	4-hr RSC	5+	1,2,3	0.37	2.12	1.48		
		12-hr RSC					1.11	4.72	24.01
	Punchout Repairs B(8)	4-hr RSC	5+	1,2,3	0.13	0.84	1.60		
		12-hr RSC					0.68	2.32	8.88
	Punchout Repairs C(9)	4-hr RSC	5+	1,2,3	0.50	7.00	16.00		
		12-hr RSC					2.50	14.50	83.00
Rehabilitation									
Flexible / Composite	Flexible Overlay w/ Slab Replacement **(FO + JPCP SR)**	4-hr RSC	10	1,2,3	0.13	0.84	1.60		
	Flexible Overlay w/ Slab Replacement **(FO + JPCP SR)**	12-hr RSC					0.68	2.32	8.88
	Mill, Slab Replacement & Overlay **(MSRO)**	4-hr RSC	10	1,2,3	0.27	2.12	4.48		
	Mill, Slab Replacement & Overlay **(MSRO)**	12-hr RSC					1.11	4.72	24.01
	Mill, Slab Replacement & Overlay **(MSRO)**	4-hr RSC	20		0.19	2.01	4.25		
	Mill, Slab Replacement & Overlay **(MSRO)**	12-hr RSC					0.88	4.38	22.94
	Crack, Seat, & Flexible Overlay **(CSFOL)**		10	1,2,3	0.28	0.70	1.41	2.72	8.57
			20		0.23	0.44	1.03	2.08	6.58
	Replace with Flexible		20	1,2,3	0.10	0.40	0.67	1.23	3.95
			40		0.06	0.30	0.51	0.83	2.81
	Replace with Composite	4-hr RSC	20	1,2,3	0.01	0.04	0.18		
		12-hr RSC					0.10	0.13	0.60
		4-hr RSC	40	1,2,3	0.01	0.03	0.15		
		12-hr RSC					0.10	0.11	0.50
Rigid - Jointed Plain Concrete Pavement (JPCP)	Lane Replacement	4-hr RSC	20	1,2,3	0.02	0.09	0.18		
		12-hr RSC					0.12	0.16	0.70
		4-hr RSC	40	1,2,3	0.02	0.05	0.16		
		12-hr RSC					0.10	0.15	0.60
Rigid - Continuously Reinforced Concrete Pavement (CRCP)	Lane Replacement	4-hr RSC	20	1,2,3	0.01	0.03	0.13		
		12-hr RSC					0.08	0.11	0.50
		4-hr RSC	40	1,2,3	0.01	0.02	0.12		
		12-hr RSC					0.06	0.10	0.40

FO= Flexible Overlay JPCP = Jointed Plain Concrete Pavement SR = Slab Replacement RSC = Rapid Set Concrete
CRCP = Continuously Reinforced Concrete Pavement

Notes:

UD - Under Development. See Office of Pavement Design for Assistance

(1) Refer to Appendix 1, "Glossary and List of Acronyms" for definitions of terms used in the table.

(2) Refer to Appendix 3 for a expanded version of the table.

(3) Production rates are based on the lower end of the representative assumptions for the range and are applied consistently throughout the table. These rates are only for calculating future user costs for the procedures in this manual and not for any other purpose. More project specific user costs for some freeway situations can be obtained from the CA4PRS software.

(4) 24-hour continuous closure with 16 hours of operation per day

(5) 24-hour continuous closure with 24 hours of operation per day

(6) 55-hour extended closure over the weekend

(7) Punchout Repair A involves **significant** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced concrete pavements that had previous punchout repairs and a flexible overlay.

(8) Punchout Repair B involves **moderate** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced concrete pavements where the total number of current and previous punchout repairs exceed 4 per mile.

(9) Punchout Repair C involves **minor** punchout repairs and 0.15' of flexible overlay. It applies to continuously reinforced concrete pavements that where the total number of current and previous punchout repairs do not exceed 4 per mile.

Table 14. Caltrans Climate Region Classification

Caltrans Climate Regions	Climate Regions for Pavement M&R Schedules
North Coast	All Coastal
Central Coast	
South Coast	
Inland Valley	Inland Valley
High Mountain	High Mountain and High Desert
High Desert	
Desert	Desert
Low Mountain	Low Mountain and South Mountain
South Mountain	

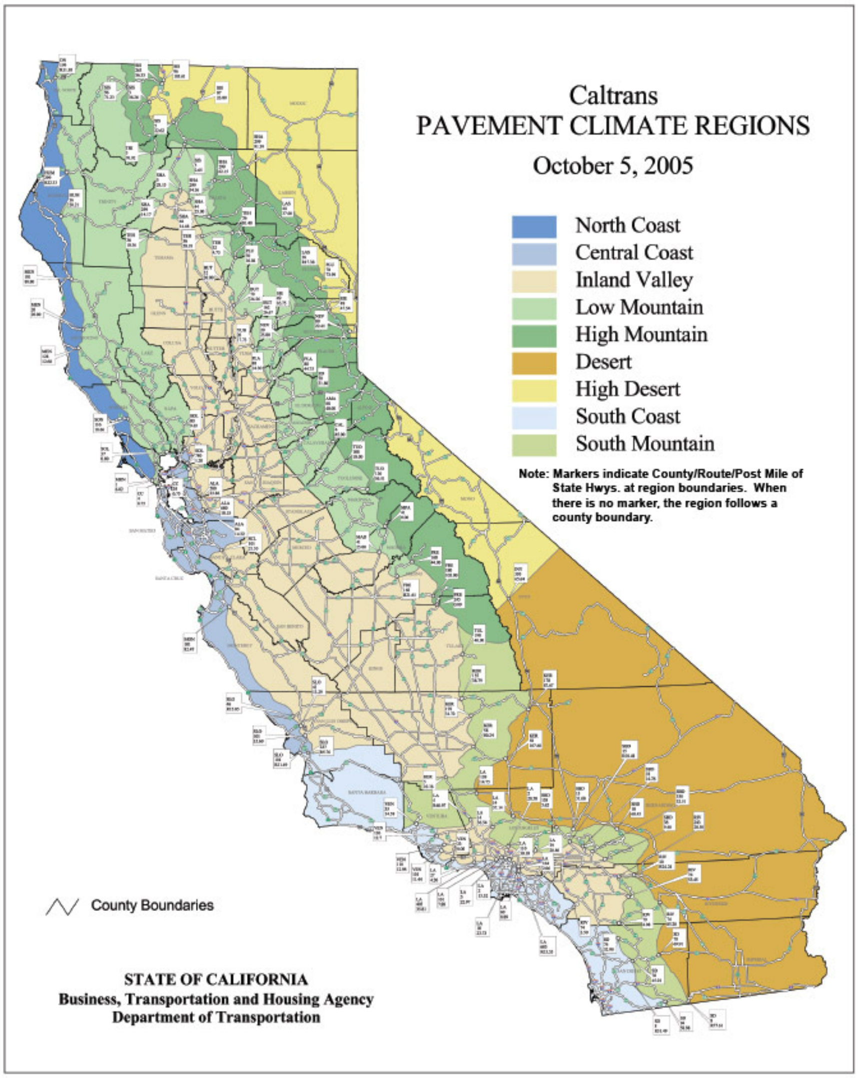

Figure A4-1. Map of Caltrans Climate Regions

(This map can be found at http://www.dot.ca.gov/hq/esc/Translab/ope/Climate.html)

Table 15. Passenger Car Equivalent Factors

	Type of Terrain		
	Level	**Rolling**	**Mountainous**
E	1.5	2.5	4.5

E = passenger car equivalent (passenger cars/heavy vehicle)